# Nutrient, Sediment, and Dissolved Oxygen TMDLs for Indian Creek Dam in Hettinger County, North Dakota

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## 1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Indian Creek Dam is a small reservoir on Indian Creek, a tributary to the Cannonball River, and is located in Hettinger County, North Dakota (Figure 1). Completed in 1978, Indian Creek Dam was constructed for the purpose of anticipated high nutrient and sediment runoff from the contributing watershed. To help alleviate the negative water quality impacts, an automatic hypolimnion drawdown was installed, and repairs were made to two small dams on the southwest and western drainages to act as sediment retention ponds.

The Indian Creek Watershed is a 10,733 acre watershed located in the Cannonball Drainage of south central Hettinger County (Figure 1). The watershed of Indian Creek Dam lies completely within the Northwestern Great Plains ecoregion (43a); which is characterized by a semiarid rolling plain of shale, siltstone, and sandstone with occasional buttes and badlands. The topography of this ecoregion was largely unaffected by glaciation and retains its original soils and complex stream drainage pattern. Native grasslands persist in areas of steep or broken topography but have been largely replaced by spring wheat and alfalfa over most of the ecoregion. However, agriculture is often hindered by erratic precipitation patterns and limited opportunities for irrigation. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Indian Creek Dam and its watershed.

**Table 1. General Characteristics of Indian Creek Dam and its Watershed.**

| | |
|---|---|
| **Legal Name** | Indian Creek Dam |
| **Major Drainage Basin** | Lower Missouri River Basin |
| **Nearest Municipality** | Regent, North Dakota |
| **Assessment Unit ID** | ND-10130204-006-L_00 |
| **County Location** | Hettinger County, North Dakota |
| **Physiographic Region** | Missouri Plateau |
| **Latitude** | 46.33362 |
| **Longitude** | -102.63505 |
| **Surface Area** | 196.3- acres |
| **Watershed Area** | 10,733- acres |
| **Average Depth** | 12.3- feet |
| **Maximum Depth** | 32- feet |
| **Volume** | 2,432.2 acre-feet |
| **Tributaries** | Indian Creek, unnamed tributaries |
| **Type of Waterbody** | Constructed Reservoir |
| **Dam Type** | Constructed Earthen Dam |
| **Fishery Type** | Trout, Walleye, Northern Pike, Bluegill, and Smallmouth Bass |

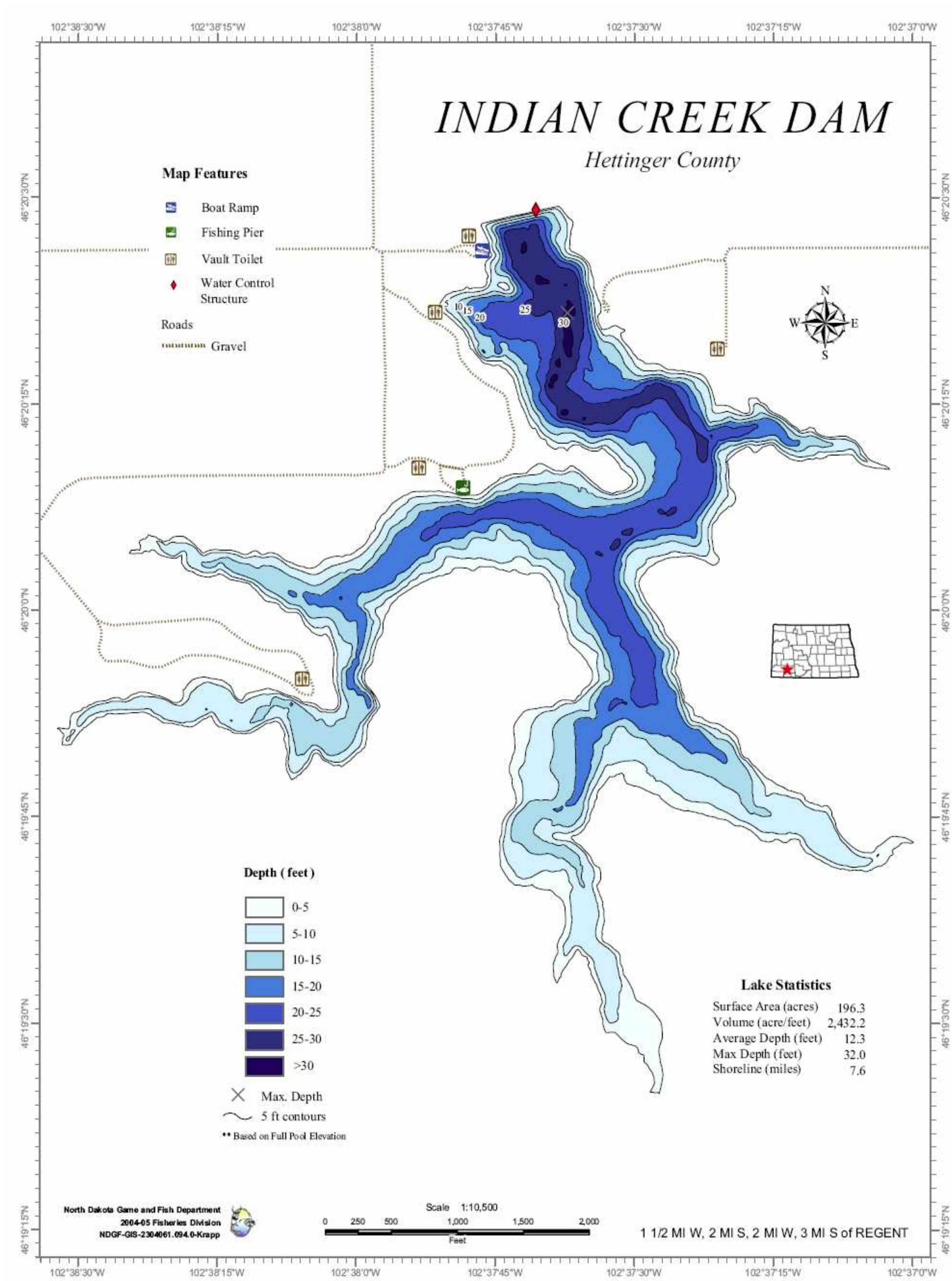


**Figure 1. North Dakota Game and Fish Contour Map of Indian Creek Dam.**

## 1.1 Clean Water Act Section 303(d) Listing Information

As part of the Clean Water Act 2004 section 303(d) listing process, the North Dakota Department of Health has identified Indian Creek Dam as an impaired waterbody (Table 2). Based on a Trophic State Index (TSI) score, aquatic life and recreation uses of Indian Creek Dam are impaired. Aquatic life is listed as impaired due to nutrients, sedimentation, and low dissolved oxygen. Recreational use is impaired due to nutrients, although, North Dakota's section 303(d) list does not provide any potential sources of these impairments. Indian Creek Dam has been classified as a Class 3 warm-water fishery. Class 3 lakes or reservoirs are "capable of supporting growth and propagation of nonsalmonid fishes and associated aquatic biota" (NDDoH, 1991).

**Table 2. Indian Creek Dam Section 303(d) Listing Information (NDDoH, 2004).**

| | |
|---|---|
| **Assessment Unit ID** | ND-10130204-006-L_00 |
| **Waterbody Name** | Indian Creek Dam |
| **Water Quality Standard Class** | 3 -Warm-water fishery |
| **Impaired Uses** | Fish and Other Aquatic Biota (fully supporting but threatened), Recreation (fully supporting but threatened) |
| **Pollutants of Concern** | Nutrients, Dissolved Oxygen, Sedimentation |
| **Priority** | High |
| **First Appeared on 303(d) list** | 1998 |

## 1.2 Topography

Indian Creek Dam is located in the Missouri Plateau portion of the Northwestern Great Plains ecoregion. The landscape is dominated by a mosaic of spring wheat, alfalfa, and grazing land that covers the short-grass prairie. However, native grasslands still persist in steep and broken terrain. The topography of the area is composed of gently rolling to hilly uplands except near prominent buttes and badlands areas. This region also contains well defined drainages in the form of intermittent and perennial streams. Soils present in the watershed are moderately deep to shallow, a product of weathered loamy glacial till or soft bedrock. Additionally, soils are moderately fertile to fertile, well drained and susceptible to wind and water erosion. Slopes are mainly gentle with relief ranging from 300-500 feet (NDDoH, 1993). Some areas are either non-glaciated, or were glaciated so long ago as to have no glacial evidence remaining. The elevation in Hettinger County ranges from 2,590 feet MSL in the northwest to approximately 2,720 feet MSL in the southeast. Figure 2 shows an aerial photo of the Indian Creek Dam watershed and the gentle relief present in this portion of Hettinger County.

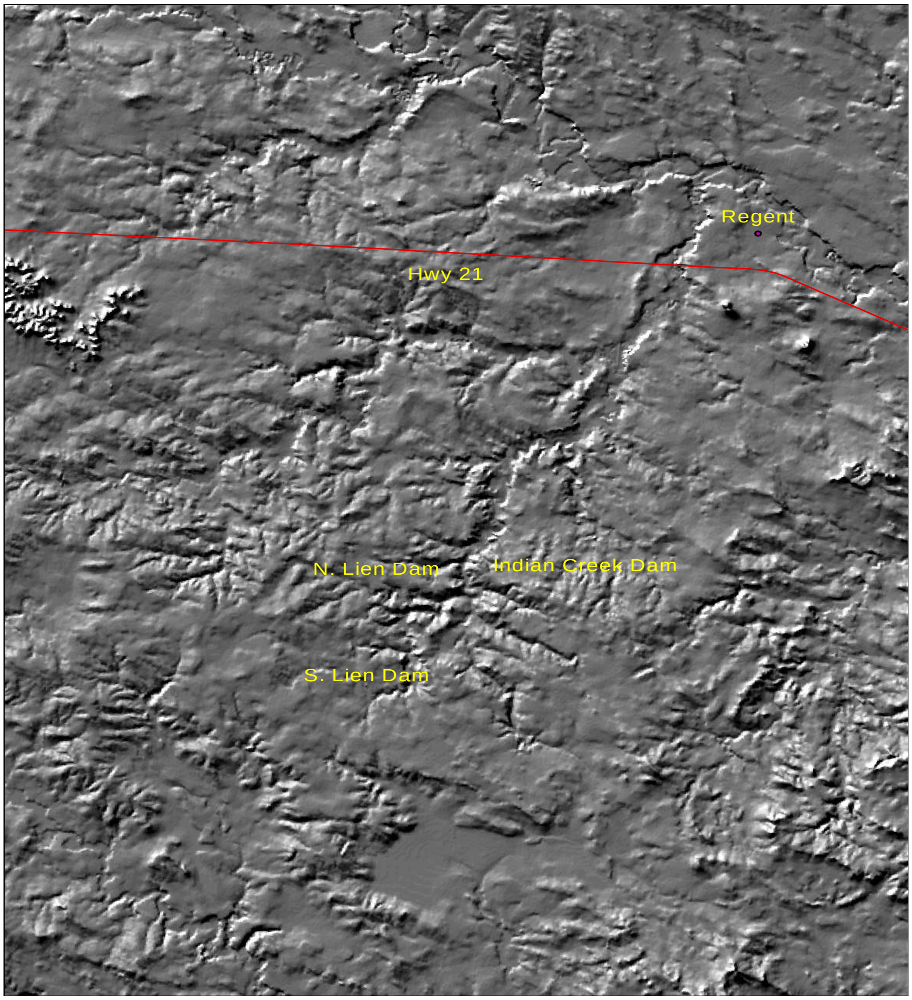


**Figure 2. Aerial Depiction of Indian Creek Dam and Watershed.**

### 1.3 Land Use/Land Cover

Land use in the Indian Creek watershed is primarily agricultural (87%). Approximately 77% of land within the watershed is used for cropland, 7% pasture land, 1% hay land, and 2% CRP respectively (Figure 3). The remainder of the land is in farmstead and feedlot areas ("other" in Figure 3), or wildlife management area habitat. There are no large urban areas within the watershed. However, several farmsteads are present throughout the area. Potential natural vegetation in this watershed includes: prairie sandreed, little bluestem, blue grama, and needlegrass.

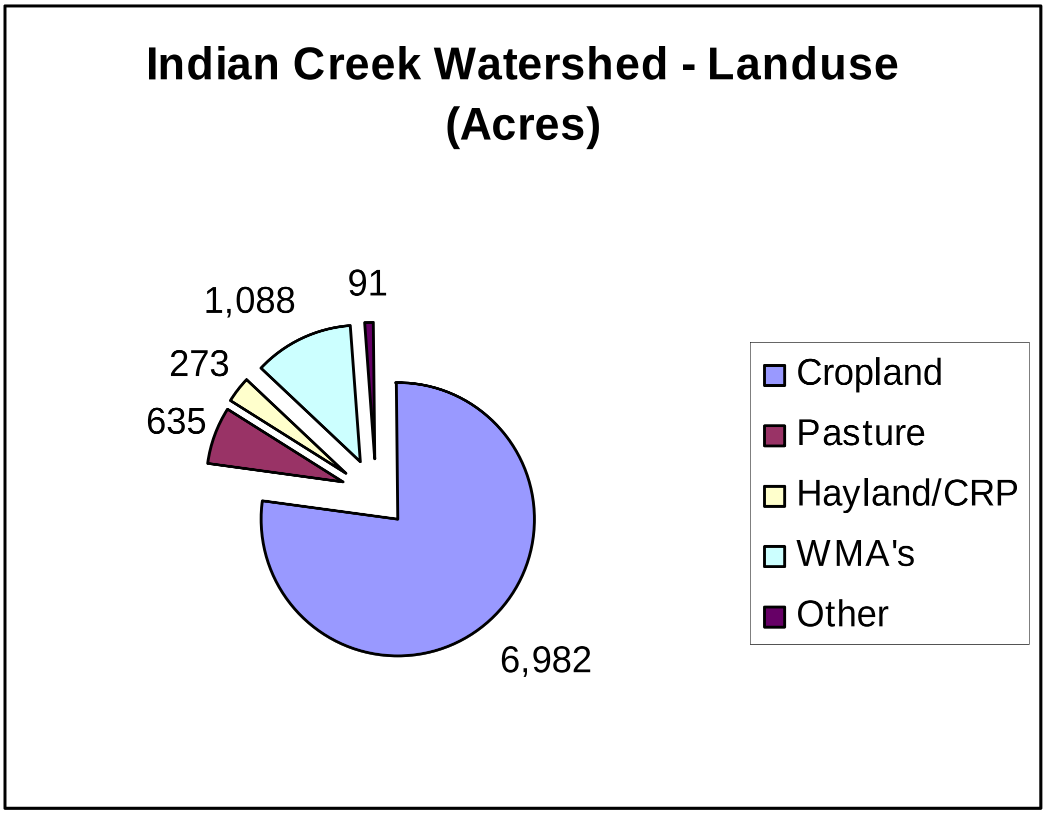


**Figure 3. Estimated Land Use Data Coverage for Indian Creek Dam.**

### 1.4 Climate and Precipitation

Indian Creek Dam and its watershed lie within the southwestern climate division of North Dakota. Southwestern North Dakota has a typical continental climate characterized by large annual, daily, and day-to-day temperature changes, light to moderate precipitation, and nearly continuous air movement. The normal air temperature in January is 16°F, while the normal air temperature in July is 69°F (NDAWN, 2006). An annual average temperature of 56°F has been recorded in Mott, North Dakota, a near municipality, over the last twenty years. These extreme seasonal variations in temperature are typical of the climate in this region. Average maximum monthly temperature in Mott between 1983 and 2004 is shown in Figure 4, while average monthly precipitation totals 15.76 inches per year during the same time period (Figure 5) (NDAWN, 2006). June is the wettest month of the year with average precipitation of 2.88 inches. Precipitation events tend to be brief and intense and occur mainly during the months of May through August, with little precipitation from November through March.

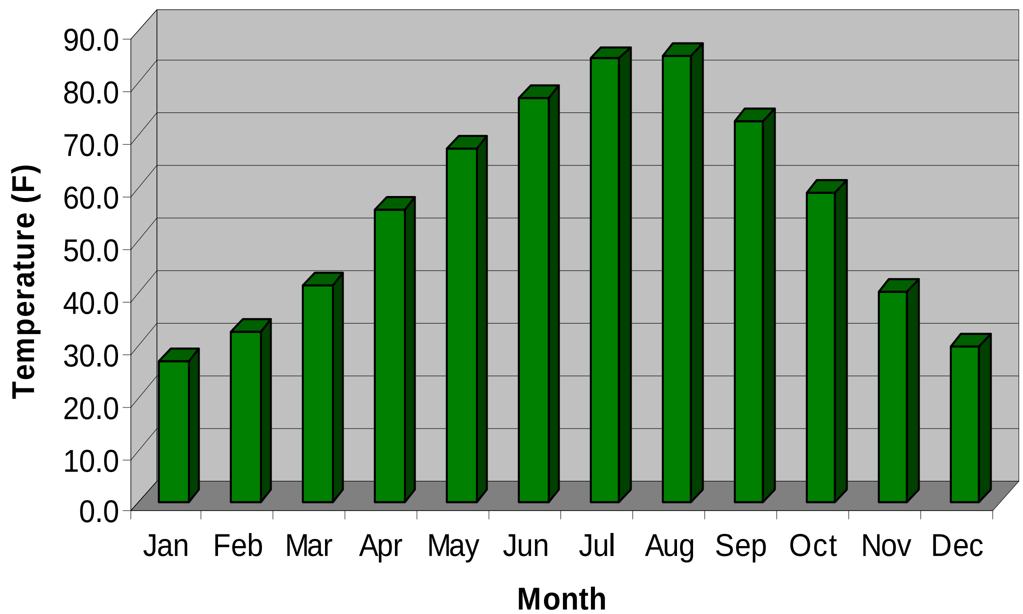


**Figure 4. Average Maximum Monthly Temperature From 1983-2004 at the North Dakota Agriculture Weather Network (NDAWN), Mott, ND Weather Station.**

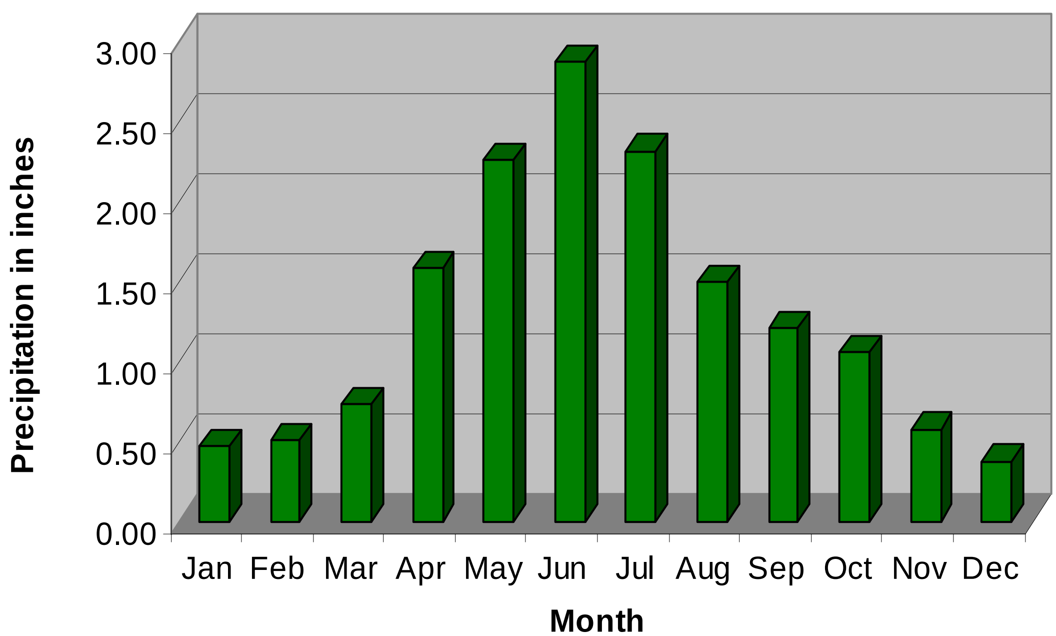


**Figure 5. Average Monthly Precipitation From 1983-2004 at the North Dakota Agriculture Weather Network (NDAWN), Mott, ND Weather Station.**

## 1.5 Available Water Quality Data

### 1.5.1 1991-1992 Lake Water Quality Assessment Project

A Lake Water Quality Assessment (LWQA) was conducted on Indian Creek Dam in 1991-1992. Samples were taken twice during the summer of 1991 and once during the winter of 1991-1992. The samples were collected at one site located in the deepest area of the lake (380765). Water column samples consisted of three separate depths (1, 3, and 6 meters in the summer) and (1, 3, and 5 meters during the winter). During the summer water quality sampling periods, Indian Creek Dam was not thermally stratified. Dissolved oxygen concentrations were near saturation to a depth of 3 to 5 meters and were adequate to maintain aquatic life. Winter samples also showed no thermal stratification, with dissolved oxygen concentrations in January at approximately 3 mg $L^{-1}$ or less throughout the water column.

The 1991-1992 LWQA Project characterized Indian Creek Dam as a lake having extremely hard water, rich in both minerals and nutrients. The volume weighted mean for total phosphate as P was 0.195 mg $L^{-1}$. The volume weighted means are calculated by weighing the parameter analyzed by the percentage of water volume represented at each depth interval. Although this is a relatively low concentration compared to many lakes in North Dakota, it does exceed the state's target concentration of 0.02 mg $L^{-1}$. Trophic status was assessed using the water quality data collected during the summer of 1991, indicating that Indian Creek Dam is hypereutrophic. Secchi disk transparency readings of 1 meter or less were recorded during summer sampling. Total phosphate as P concentrations at the surface were between 0.170 and 0.274 mg $L^{-1}$ and chlorophyll-a concentrations were between 0.019 and 0.039 mg $L^{-1}$. Additional evidence supporting this trophic status assessment included: a large macrophyte biomass covering 20-25 percent of the lake surface area, a phytoplankton community dominated by one or two species of blue-green algae, frequent nuisance algal blooms, and low dissolved oxygen concentrations below the hypolimnion (as well as the majority of the water column during ice cover conditions).

### 1.5.2 2001-2005 Indian Creek Dam TMDL Project

The Hettinger County Soil Conservation District (SCD) conducted a water quality assessment of Indian Creek Dam and its watershed from 2001-2005. The SCD followed the methodology for water quality sampling found in the Quality Assurance Project Plan (QAPP) for the Indian Creek Dam TMDL Project (NDDoH, 2001). Sampling and analysis variables are shown in Table 3.

**Table 3. Indian Creek Dam Sampling and Analysis Variables.**

| Field Measurements | General Chemical Variables | Nutrient Variables | Biological Variables |
|---|---|---|---|
| Secchi Disk Transparency | pH | Total Phosphorus | Chlorophyll-a |
| Temperature | Specific Conductance | Dissolved Phosphorus | Phytoplankton |
| Dissolved Oxygen | Major Anions & Cations | Total Nitrogen | Fecal Coliform |
| | Total Suspended Solids | Total Kjeldahl Nitrogen | |
| | | Nitrate plus Nitrite Nitrogen | |
| | | Ammonia Nitrogen | |

Stream Monitoring
Sampling frequency for the stream sampling sites was stratified to coincide with the typical hydrograph for the region. This sampling design would result in more frequent samples during spring and early summer when stream discharge is typically at its peak; and less frequent samples during the summer and fall. Sampling would be discontinued during winter ice cover conditions, and terminated if the stream stopped flowing. If the stream should begin flow again, water quality sampling would be reinitiated at the same sampling locations (Figure 6).

Lake Monitoring
In order to accurately account for temporal variation in lake water quality, the lake was sampled twice per month during the open water season and monthly during ice cover conditions.

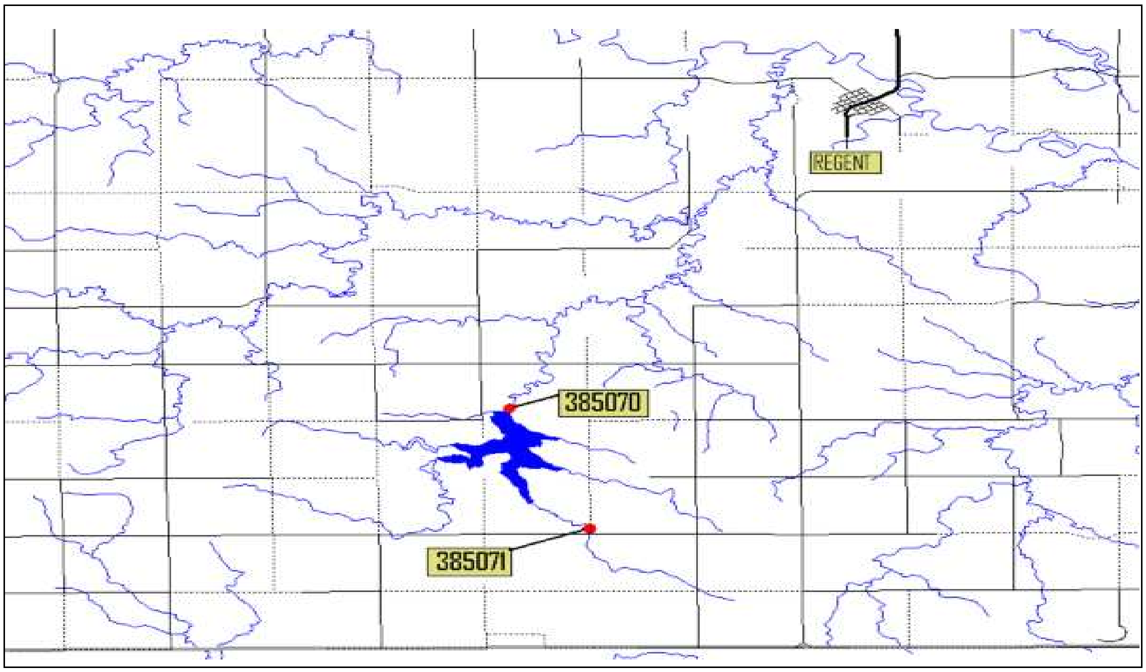


**Figure 6. Indian Creek Dam Sampling Locations and Station IDs.**

Nutrient Data

Surface water quality parameters were monitored in Indian Creek Dam at two sample stations between October 2001 and February 2005. Sample parameters and average volume weighted mean concentrations are provided in Table 4. Average concentrations of total and dissolved phosphorus were higher at the inlet, while total nitrogen and total Kjeldahl nitrogen were greater at the deepest site of the reservoir. Indian Creek Dam contained an average total nitrogen to total phosphorus ratio of nearly 37:1 at site 380765 (Table 4). Ratios above 7.2 generally indicate that phosphorus is the limiting nutrient (Chapra, 1997).

**Table 4. Data Summary for Indian Creek Dam TMDL Project 2001-2005.**

| Parameter | Inlet Stream Site #385071 | | | | | Deepest Site #380765 | | | | | Volume-weighted Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Max | Median | Avg | Min | N | Max | Median | Avg | Min | |
| Total Phosphorus (mg $L^{-1}$) | 42 | 0.523 | 0.125 | 0.140 | 0.004 | 62 | 0.098 | 0.049 | 0.046 | 0.008 | 0.046 |
| Dissolved Phosphorus (mg $L^{-1}$) | 35 | 0.354 | 0.010 | 0.033 | 0.004 | 56 | 0.102 | 0.006 | 0.019 | 0.004 | 0.018 |
| Total Nitrogen (mg $L^{-1}$) | 42 | 3.260 | 1.460 | 1.636 | 1.140 | 62 | 2.920 | 1.640 | 1.676 | 1.260 | 1.692 |
| Total Kjeldahl Nitrogen (mg $L^{-1}$) | 42 | 2.570 | 1.410 | 1.505 | 0.700 | 62 | 2.900 | 1.620 | 1.645 | 1.240 | 1.662 |
| Nitrate/Nitrite (mg $L^{-1}$) | 42 | 2.120 | 0.020 | 0.131 | 0.020 | 62 | 0.090 | 0.020 | 0.031 | 0.020 | 0.03 |
| *chlorophyll-a* (µg/L) | N/A | N/A | N/A | N/A | N/A | 16 | 76.40 | 11.00 | 16.90 | 3.00 | N/A |
| Secchi Disk (meters) | N/A | N/A | N/A | N/A | N/A | 15 | 2.50 | 1.50 | 1.34 | 0.50 | N/A |

Nutrient concentrations from Indian Creek Dam in 2001-2005 were compared to data collected from Indian Creek Dam in 1991-1992. Average nutrient concentrations reported for the 1991-1992 LWQA were higher when compared to the 2001-2005 Indian Creek Dam Assessment. The 2001-2005 Indian Creek Dam Assessment showed reductions in nutrient concentrations such as nitrate-nitrite, total Kjeldahl nitrogen, and total phosphorus when compared to the 1991-1992 LWQA data (Table 5).

**Table 5. Nutrient Concentration Comparisons at Indian Creek Dam.**

| Parameter | Indian Creek Dam 1991-1992 | Indian Creek Dam 2001-2005 |
|---|---|---|
| Nitrate/Nitrite (mg $L^{-1}$) | 0.035 | 0.031 |
| Total Kjeldahl Nitrogen (mg $L^{-1}$) | 2.820 | 1.645 |
| Total Phosphorus (mg $L^{-1}$) | 0.195 | 0.046 |

Dissolved Oxygen and Temperature Data

Dissolved oxygen and temperature were monitored at the deepest area site of Indian Creek Dam from October 2001-February 2005. Raw data is provided in Appendix C, while Figures 7-10 illustrate the results of the temperature and dissolved oxygen data for the deepest monitoring site, respectively. Samples were collected at 1-meter intervals during ice cover and open water periods. During the summer sampling of 2002, Indian Creek Dam was thermally stratified on July 24, 2002 between four and five meters of depth. At that time dissolved oxygen concentrations ranged from 10.8 mg $L^{-1}$ at the surface, and declined in concentration from 5.06 mg $L^{-1}$ to 4.19 mg $L^{-1}$ at 4-5 meters of depth. Based on the 2001-2003 data there appears to be a period during the summer season (July) when dissolved oxygen consistently falls below the 5 mg $L^{-1}$ state standard in the hypolimnion. When comparing the dissolved oxygen concentrations in the deepest area site of Indian Creek Dam during 2001-2003 and 2004-2005, the concentrations of dissolved oxygen during the summer of 2004 were below the 5 mg/$L^{-1}$ state standard during July, August, and September. The data indicates that the summer months of July-September are critical for dissolved oxygen concentrations in Indian Creek Dam, especially during dry years. All other months show results above the 5 mg/$L^{-1}$ state standard. The cause-and-effect relationship between nutrients, water temperature, plant growth and decomposition, and the resulting low dissolved oxygen levels in a waterbody is well established in the scientific arena.

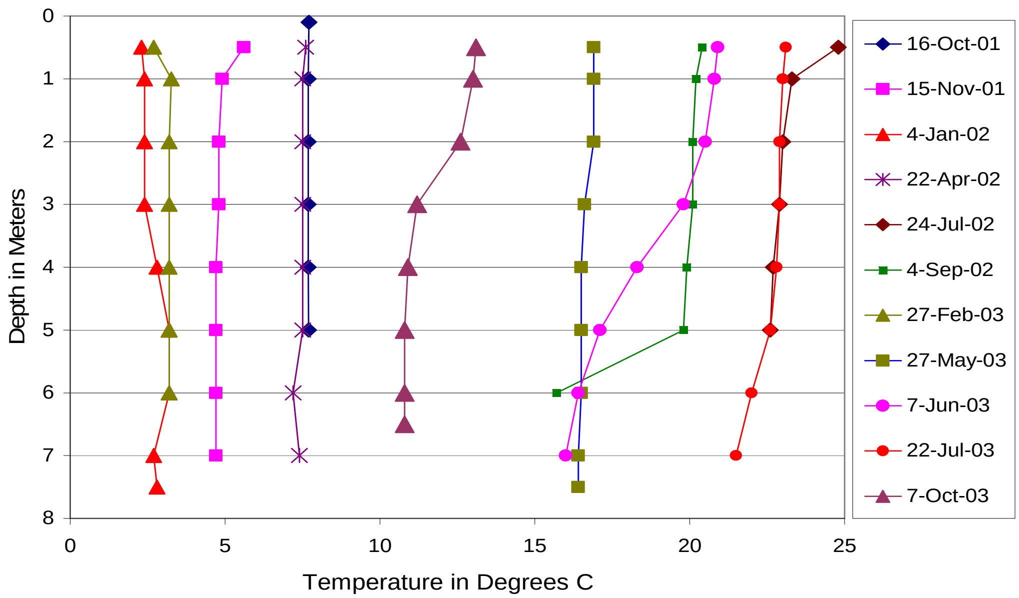


**Figure 7. Summary of Temperature Data for Indian Creek Dam's Deepest Area Site (380765), 2001-2003.**

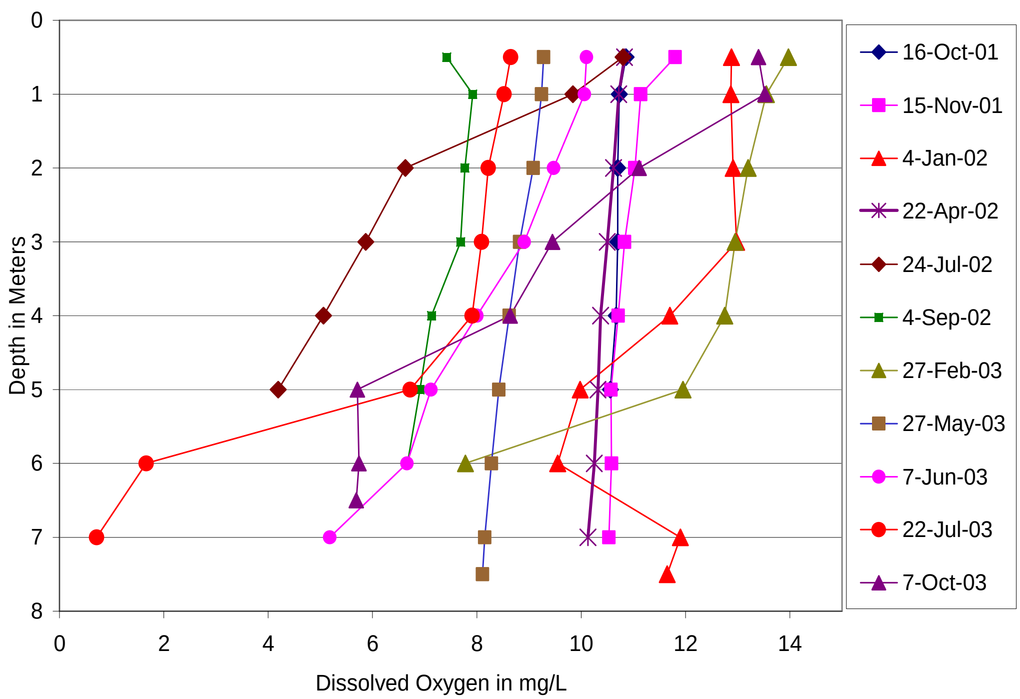


**Figure 8. Summary of Dissolved Oxygen Concentrations for Indian Creek Dam's Deepest Area Site (380765), 2001-2003.**

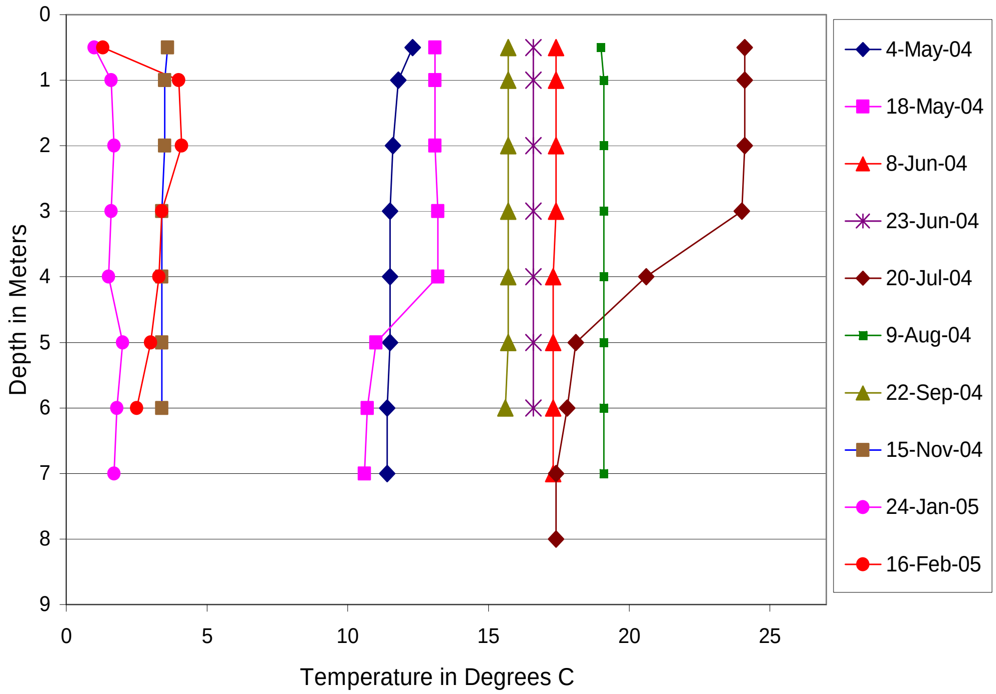


**Figure 9. Summary of Temperature Data for Indian Creek Dam's Deepest Area Site (380765), 2004-2005.**

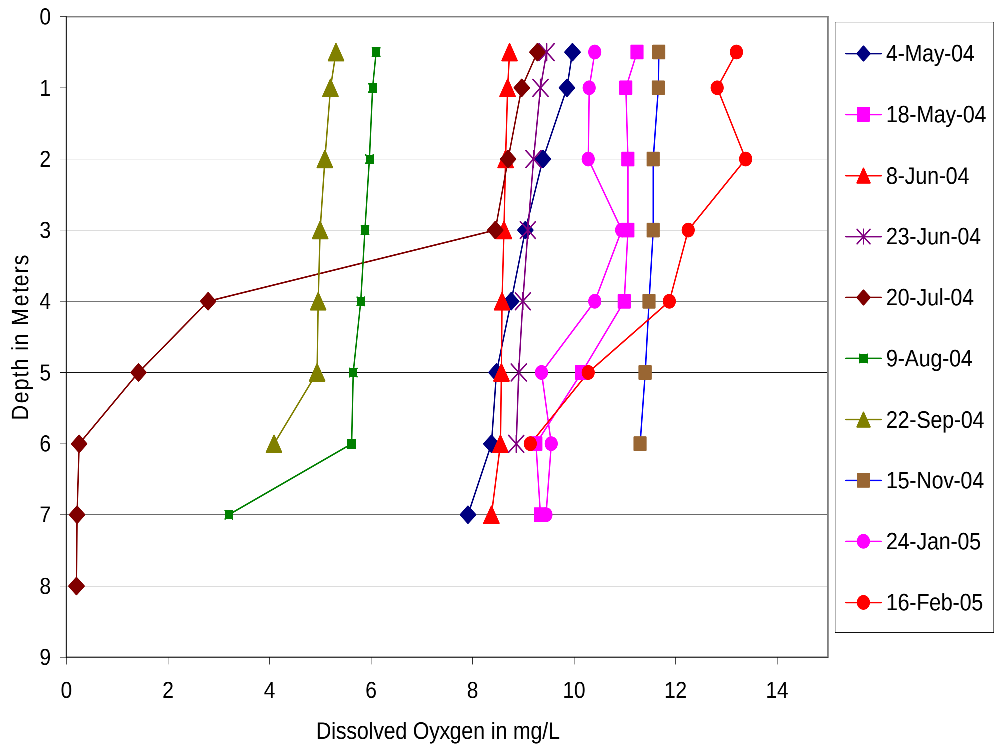


**Figure 10. Summary of Dissolved Oxygen Profiles for Indian Creek Dam's Deepest Area Site (380765), 2004-2005.**

Secchi Depth and In-Lake Total Suspended Solids

Secchi depth data were collected by SCD staff between October 2001 and September 2004 (Table 6). As shown in Table 6, the average Secchi depth for the deepest sampling site was 1.34 meters for Indian Creek Dam. Based on Secchi depth, the TSI score for this reservoir is 57.7 (well within the eutrophic range).

While Secchi depths were taken for only 4 months of the year on average from 2001-2004, the data shows that visibility throughout the water column was lowest during September and October. The greatest Secchi depths on Indian Creek Dam were measured during the optimal growing season months of June and July (Table 6). Water clarity in a reservoir can be affected by many factors. Algal biomass, total suspended solids, and other debris all affect Secchi depth measurements.

**Table 6. Average Monthly Secchi Depths in Indian Creek Dam 2001-2004.**

| Month | Average Secchi Depth (M) | Month | Average Secchi Depth (M) |
|---|---|---|---|
| January | NA | July | 1.45 |
| February | NA | August | 1.5 |
| March | NA | September | 1.13 |
| April | 0.75 | October | 0.75 |
| May | 1.17 | November | NA |
| June | 2.08 | December | NA |

Tributary Total Suspended Solids

One hundred eleven total suspended solid (TSS) samples were collected by the Slope-Hettinger SCD staff between April 2002 and September 2004. TSS samples were collected from the inlet site (385071) and outlet site (385070) of Indian Creek Dam. Average TSS concentrations at the inlet and outlet sites were 19.3 and 7.2 mg $L^{-1}$ respectively (Table7). As evidenced by table seven, suspended solids are being retained within the reservoir. This data shows that samples taken from the outlet contained less than half of the TSS concentration taken from samples at the inlet.

**Table 7. Average Total Suspended Solid Concentrations for the Indian Creek Dam Inlet and Outlet Sites (2002-2004).**

| Site ID | Site Description | Average TSS (mg/L) |
|---|---|---|
| 385071 | Inlet | 19.3 |
| 385070 | Outlet | 7.2 |

## 2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for waters on a state's Section 303(d) list. A TMDL is defined as “the sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background” such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. The purpose of a TMDL is to identify the pollutant load reductions or other actions that should be taken so that impaired waters will be able to attain water quality standards. TMDLs are required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. Separate TMDLs are required to address each pollutant or cause of impairment (i.e., nutrients, sediment).

## 2.1 Narrative Water Quality Standards

The North Dakota Department of Health has set narrative water quality standards, which apply to all surface waters in the state. The narrative standards pertaining to nutrient impairments are listed below (NDDoH, 2001).

- All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to humans, animals, plants, or resident aquatic biota.

- No discharge of pollutants, which alone or in combination with other substances shall:
  1) Cause a public health hazard or injury to environmental resources;
  2) Impair existing or reasonable beneficial uses of the receiving waters; or
  3) Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDoH has set a biological goal for all surface waters in the state. The goal states that "the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites," (NDDoH, 2001).

## 2.2 Numeric Water Quality Standards

Indian Creek Dam is classified as a Class 3 warm water fishery. Class 3 fisheries are defined as waterbodies "capable of supporting growth and propagation of nonsalmonid fishes and associated aquatic biota" (NDDoH, 1991). All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The North Dakota State Water Quality Standards state that lakes shall use the same numeric criteria as Class 1 streams. This includes the state standard for dissolved oxygen set at no less than 5 mg $L^{-1}$. State standards for lakes and reservoirs also specify guidelines for nitrogen (1.0 mg $L^{-1}$ as nitrate) and phosphorus (0.1 mg $L^{-1}$ as total phosphorus) (Table 8).

**Table 8. Numeric Standards Applicable for North Dakota Lakes and Reservoirs (NDDoH, 2001).**

| Parameter | | Guidelines | Limit |
|---|---|---|---|
| Guidelines or Standards for Classified Lakes | | | |
| | Nitrates (dissolved) | 1.0 mg $L^{-1}$ | Maximum allowed[1] |
| | Phosphorus (total) | 0.1 mg $L^{-1}$ | Maximum allowed[1] |
| | Dissolved Oxygen | 5 mg $L^{-1}$ | Not less than |
| Guidelines for goals in a lake improvement or maintenance program | | | |
| | $NO_3$ as N | 0.25 mg $L^{-1}$ | Goal |
| | $PO_4$ as P | 0.02 mg $L^{-1}$ | Goal |

**[1] "Interim guideline limits"**

## 3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets should be based on state water quality standards, but can also include site-specific values when no numeric criteria are specified in the standard. The following sections summarize water quality targets for Indian Creek Dam based on its impaired beneficial uses. If the specific target is met, it is assumed the reservoir will meet the applicable water quality standards, including its designated beneficial uses.

### 3.1 Trophic State Index

North Dakota's 2004 Integrated Section 305(b) and Section 303(d) Water Quality Assessment Report indicates that Carlson's Trophic State Index (TSI) is the primary indicator used to assess beneficial uses of the state's lakes and reservoirs (NDDoH, 2004). Trophic status is the measure of productivity of a lake or reservoir and is directly related to the level of nutrients (phosphorus and nitrogen) entering the lake or reservoir from its watershed. Lakes tend to become eutrophic (more productive) with higher nitrogen and phosphorus inputs. Eutrophic lakes often have nuisance algal blooms, limited water clarity, and low dissolved oxygen concentrations that can result in impaired aquatic life and recreational uses. Carlson's TSI attempts to measure the trophic state of a lake using nitrogen, phosphorus, chlorophyll-a, and Secchi disk depth measurements (Carlson, 1977).

Trophic State Index (TSI) values were calculated for total phosphorus, chlorophyll-*a*, and secchi disk at Indian Creek Dam. The highest TSI value was for total phosphorus at 60 while Chlorophyll –*a* and secchi depth values were 59 and 56, respectively (Table 9). Based on Carlson's TSI and water quality data collected between October 2001 and September 2004, Indian Creek Dam was generally assessed as a eutrophic lake (Table 9). Eutrophic lakes are characterized by large growths of weeds, blue-green algal blooms, and low dissolved oxygen concentrations. These lakes may experience periodic fish kills and are generally characterized as having excessive rough fish populations (carp, bullhead, and sucker) that can reflect poorly on the sport fishery. Because of frequent algal blooms and excessive weed growth, eutrophic lakes often become undesirable for recreational uses such as swimming and boating.

**Table 9. Carlson's Trophic State Indices for Indian Creek Dam.**

| Parameter | Relationship | Units | TSI Value | Trophic Status |
|---|---|---|---|---|
| Chlorophyll-*a* | TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)] | µg/L | 59 | eutrophic |
| Total Phosphorus (TP) | TSI (TP) = 4.15 + 14.42[ln(TP)] | µg/L | 60 | eutrophic |
| Secchi Depth (SD) | TSI (SD) = 60 - 14.41[ln(SD)] | meters | 56 | eutrophic |

TSI < 40 - Oligotrophic (least productive)
TSI 40-50 Mesotrophic
TSI 50-60 Eutrophic
TSI > 60 - Hypereutrophic (most productive)

The reasons for the different TSI values estimated for Indian Creek Dam are varied. According to the phosphorus TSI value, Indian Creek Dam is a productive lake (eutrophic) (Table 9). Carlson and Simpson (1996) suggest that if the phosphorus and secchi depth TSI values are relatively similar and higher than the chlorophyll-*a* TSI value, then dissolved color or nonalgal particulates dominate light attenuation. It follows that, as is the case with Indian Creek Dam, if the secchi depth and chlorophyll-*a* TSI values are similar, then chlorophyll-*a* is dominating light attenuation. Carlson and Simpson (1996) also state that a nitrogen index value might be a more universally applicable nutrient index than a phosphorus index, but it also means that a correspondence of the nitrogen index with the chlorophyll-a index cannot be used to indicate nitrogen limitation.

A Carlson's TSI target of 53.75 based on total phosphorus was chosen for the Indian Creek Dam endpoint. While this target will not bring concentrations of total phosphorus to the NDDoH State Water Quality Standard guideline for lakes (0.02 mg/L), it should result in a change of trophic status for the lake from eutrophic to borderline mesotrophic during all times of the year. Given the size of the lake, the probable amount of phosphorus in bottom sediments, nearly constant wind in North Dakota causing a mixing effect, and few cost effective ways to reduce in-lake nutrient cycling, this was determined to be the best possible outcome for the reservoir. If the specified TMDL TSI target of 53.75 based on total P is met, the reservoir can be expected to meet the applicable water quality standards for aquatic life and recreational beneficial uses.

## 4.0 SIGNIFICANT SOURCES

There are no known point sources upstream of Indian Creek Dam. The pollutants of concern originated from non-point sources. Most of the land upstream from Indian Creek Dam is farmed. The remainder is used for pasture or kept as permanent herbaceous cover. There are no urban areas within the watershed. There are also no lake homes around the reservoir. However, there are small farmsteads spread throughout the watershed. The vast majority of nutrient loads are transported with overland runoff from agricultural areas. Precipitation directly to the lake's surface is another possible source of nutrients. During the assessment period of Indian Creek Dam, less than average precipitation was received in the watershed.

In addition, existing land use and AnnAGNPS modeling (see section 5.3 AnnAGNPS Watershed Model) within the Indian Creek Dam watershed indicates that the majority of NPS loading is likely coming from cropland, (77 percent of land within the watershed is cropped). A small percentage (7%) of land in the watershed is used for pasture. It is possible that a small amount of nutrient loading also originates from land used for pasture. Best management practices will also be implemented on land used for pasture in order to address loading from these lands.

## 5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream water quality targets and pollutant source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity and trophic response of the receiving waterbodies. The loading capacity is the amount of a pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the technical analysis utilized to estimate existing loads to Indian Creek Dam and the predicted trophic response of the reservoir to reductions in loading capacity.

### 5.1 Tributary Load Analysis

Watershed hydraulic and pollutant loads were estimated using actual water quality data and the annualized agricultural nonpoint source (AnnAGNPS) model. The AnnAGNPS model was developed by the US Department of Agriculture's Agricultural Research Services to model relative quantity and quality of outflow from a watershed in order to assess the pollution potential.

The AnnAGNPS model delineated sub-watersheds into inlets and an outlet in order to run the model on the Indian Creek Dam watershed. Model outputs include hydraulic and soluble sediment attached nutrient loads from each sub-watershed, as well as the lake outlet (see appendix B). Since the bathtub model also requires the load of total nitrogen and total phosphorus, these were calculated as a ratio of the soluble load. The ratios were calculated from 42 inlet samples and 74 outlet samples collected between October 16, 2001 and February 16, 2005. These data were then provided as input data to calibrate the BATHTUB eutrophication response model.

### 5.2 BATHTUB Trophic Response Model

The BATHTUB model (Walker, 1996) was used to predict and evaluate the effects of various nutrient load reduction scenarios on Indian Creek Dam. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. The model accounts for advective and diffusive transport and nutrient sedimentation. Eutrophication related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications.

The BATHTUB model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project were summarized in a format which can serve as inputs to the model.

The tributary data were analyzed and estimated by the AnnAGNPS watershed model. AnnAGNPS uses actual tributary inflow, outflow, water quality, flow data, and land use practices to estimate average mass discharge or loading that passes a river or stream site. Load is therefore defined as the mass of pollutant during a given unit of time. Output from the AnnAGNPS model may then be used to effectively calibrate the BATHTUB watershed model for further estimates of current watershed characteristics.

The reservoir data was reduced in Excel using three computational functions. These include: 1) the ability to display concentrations as a function of depth, location, or date; 2) summary statistics (mean, median, etc.); and 3) evaluation of trophic status. The output data from the Excel program were then used to calibrate the BATHTUB model.

When the input data from the AnnAGNPS model and Excel programs are entered into the BATHTUB model the user has the ability to compare predicted conditions (model output) to actual conditions using general rates and factors. The BATHTUB model is calibrated by combining tributary load estimates for the project period with in-lake water quality estimates. The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates from the project monitoring data. BATHTUB then has the ability to predict total phosphorus concentration, chlorophyll-a concentration, and secchi disk transparency and the associated TSI scores as a means of expressing trophic response.

As stated above BATHTUB can compare predicted vs. actual conditions. After calibration, the model was run based on observed concentrations of phosphorus and nitrogen, to derive an estimated annual average total phosphorus load of 2,461.2 kg and an annual average total nitrogen load of 50,160.5 kg. The model was then run to evaluate the effectiveness of a number of nutrient reduction alternatives including: 1) reducing externally derived nutrient loads; 2) reducing internally available nutrients; and 3) reducing both external and internal nutrient loads.

In the case of Indian Creek Dam, BATHTUB modeled two nutrient reduction alternatives. The first alternative reduced externally derived phosphorus. Phosphorus was used in the initial set of simulation models based on its known relationship to eutrophication and that it is controllable with the implementation of watershed Best Management Practices (BMPs) or lake restoration methods. Changes in trophic response were evaluated by reducing externally derived phosphorus loading by 25, 50, and 75 percent. Simulated reductions were achieved by reducing phosphorus concentrations in contributing tributaries and other externally delivered sources. Flow was held constant due to the uncertainty of estimating changes in hydraulic discharge with the implementation of BMPs.

**Table 10. Observed and Predicted Values for Selected Trophic Response Variables Assuming 25, 50, and 75 Percent Reductions in External Phosphorus and Nitrogen Loading.**

| Variable | Observed Value | Predicted Value | | |
|---|---|---|---|---|
| | | 25% | 50% | 75% |
| Total Phosphorus (mg/L ) | 0.05 | 0.041 | 0.031 | 0.019 |
| Total Dissolved Phosphorus (mg/L ) | 0.020 | 0.017 | 0.014 | 0.010 |
| Total Nitrogen (mg/L ) | 1.690 | 1.274 | 0.858 | 0.442 |
| Organic Nitrogen (mg/L ) | 1.630 | 1.351 | 1.068 | 0.754 |
| Chlorophyll-a (µg/L) | 18.24 | 14.03 | 9.47 | 4.39 |
| Secchi Disk Transparency (meters) | 1.34 | 1.54 | 1.87 | 2.46 |
| Carlson's TSI for Phosphorus | 60.54 | 57.78 | 53.75 | 46.47 |
| Carlson's TSI for Chlorophyll-a | 58.94 | 56.51 | 52.66 | 45.11 |
| Carlson's TSI for Secchi Disk | 55.78 | 53.74 | 50.96 | 47.05 |

To acquire a noticeable change in the tropic status the BATHTUB model predicted that a 50 percent reduction in total phosphorus loads would achieve the target of 0.031 mg $L^{-1}$ and a 0.858 mg $L^{-1}$ nitrogen load (Table 10). This reduction in phosphorus and nitrogen is predicted to result in a reservoir that is nearly mesotrophic (Figure 11).

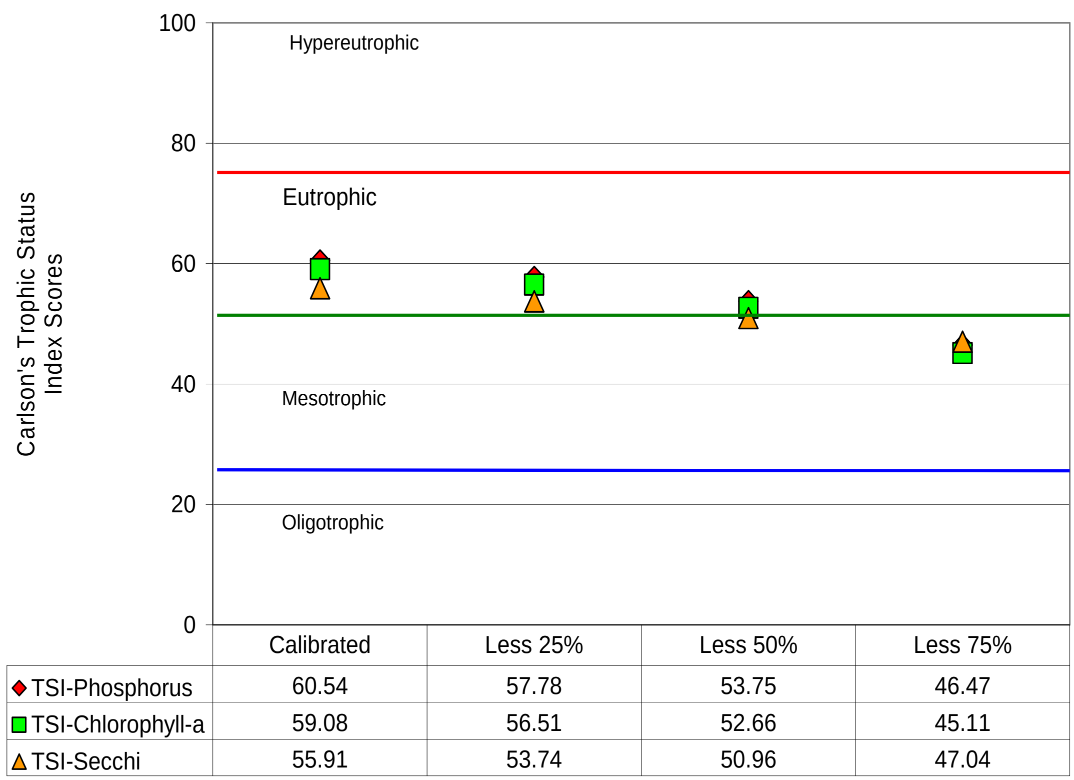


**Figure 11. Predicted Trophic Response to Phosphorus Loads of Indian Creek Dam showing the observed score and a 25, 50, and 75 Percent Load Reduction.**

### 5.3 AnnAGNPS Watershed Model

The AnnAGNPS (Annualized Agricultural Non-Point Source Pollution) model was developed by the USDA Agricultural Research Service and Natural Resource Conservation Service (NRCS) to expand the earlier AGNPS single event model. The AnnAGNPS model consists of a system of computer models used to predict nonpoint source pollution (NPS) loadings within agricultural watersheds. The continuous simulation surface runoff model contains programs for 1) input generation and editing; 2) "annualized" pollutant loading model; and 3) output reformatting and analysis.

The AnnAGNPS model uses batch processing, continual-simulation, and surface runoff pollutant loading to generate amounts of water, sediment, and chemicals (nutrients and pesticides) moving from land areas (cells) and flowing into the watershed stream network at user specified locations (reaches) on a daily basis. The water, sediment, and chemicals travel throughout the watershed reaches to the watershed outlets. Feedlots, gullies, point sources, and impoundments are special components that can be included in the cells and reaches. Each component adds water, sediment, or chemicals to the reaches.

The AnnAGNPS model is able to partition soluble nutrients and pesticides between surface runoff and infiltration. Sediment attached nutrients and pesticides are also calculated in the stream system. Sediment is divided into five particle size classes (clay, silt, sand, small aggregate, and large aggregate) and are moved separately through the stream reaches.

AnnAGNPS uses various models to develop an annualized load in the watershed. These models account for surface runoff, soil moisture, erosion, nutrients, pesticides, and reach routing. Each model serves a particular purpose and function in simulating the NPS processes occurring in the watershed.

To generate surface runoff and soil moisture, the soil profile is split into two layers. The top layer is used as the tillage layer and has properties that change (bulk density etc.). While the remaining soil profile makes up the second layer with properties that remain static. A daily soil moisture budget is calculated based on (rainfall, irrigation, and snow melt), runoff, evapotranspiration, and percolation. Runoff is calculated using the SCS Runoff Curve Number equation. These curve numbers can be modified based on tillage operations, soil moisture, and crop stage. Overland sediment erosion was determined using a modified watershed-scale version of RUSLE (Geter and Theurer, 1998).

A daily mass balance for nitrogen (N), phosphorus (P), and organic carbon (OC) are calculated for each cell. Major components considered include plant uptake N and P, fertilization, residue decomposition, and N and P transport. Soluble and sediment absorbed N and P are also calculated. Nitrogen and phosphorus are then divided into organic and mineral phases. Plant uptake N and P are modeled through a crop growth stage index (Theurer et. al. 1998).

Each pesticide is expressed in a daily mass balance. The AnnAGNPS model allows for numerous pesticides, each exhibiting their own chemical properties. Major components of the pesticide model include foliage wash-off, vertical transport in the soil profile, and degradation. Soluble and sediment absorbed fractions are calculated for each cell on a daily basis.

The reach routing model moves sediment, nutrients, and pesticides through the watershed. Sediment routing is calculated based upon transport capacity relationships using the Bagnold stream power equation (Bagnold, 1966). Routing of nutrients and pesticides through the watershed is accomplished by subdividing them into soluble and sediment attached components and are based on reach travel time, water temperature, and decay constant. Infiltration is also used to further reduce soluble nutrients. Both the upstream and downstream points of the reach are calculated for equilibrium concentrations by using a first order equilibrium model.

AnnAGNPS uses 34 different categories of input data and over 400 separate input parameters to execute the model. The input data categories can be split into five major classifications: climatic data, land characterization, field operations, chemical characteristics, and feedlot operations. Climatic data includes precipitation, maximum and minimum air temperature, relative humidity, sky cover, and wind speed. Land characterization consists of soil characterization, curve number, RUSLE parameters, and watershed drainage characterization. Field operations contain tillage, planting, harvest, rotation, chemical operations, and irrigation schedules. Additionally, feedlot operations require daily manure rates, times of manure removal, and residue amount from previous operations.

Input parameters are used to verify the model. Some input parameters may be repeated for each cell, soil type, landuse, feedlot, and channel reach. Default values are available for some input parameters; others can be simplified because of duplication. Daily climatic input data can be obtained through weather generators, local data, and/or both. Geographical input data including cell boundaries, land slope, slope direction, and landuse can be generated by GIS or DEM (digital elevation models).

Output data is expressed through an event based report for stream reaches and a source accounting report for land or reach components. Output parameters are selected by the user for the desired watershed source locations (specific cells, reaches, feedlots, point sources, or gullies) for any simulation period. Source accounting for land or reach components are calculated as a fraction of a pollutant load passing through any reach in the stream network that came from the user identified watershed source locations. Event based output data is defined as event quantities for user selected parameters at desired stream reach locations.

AnnAGNPS was utilized for the Indian Creek Dam TMDL project. The Indian Creek watershed delineation began with downloading a 30 meter digital elevation model (DEM) of Hettinger County from the United States Geological Survey (USGS) website. Delineation is defined as drawing a boundary and dividing the land within the boundary into subwatersheds in such a matter that each subwatershed has uniformed hydrological parameters (land slope, elevation, etc.).

Landuse and soil digital images were then used to extract the dominant identification of landuse and soil for each subwatershed. This process is achieved by overlaying Landsat and soil images over the subwatershed file. Each dominant soil is then further identified by its physical and chemical soil properties found in a database called National Soils Information System (NASIS) developed by the NRCS. Dominant landuse identification input parameters were obtained using the Revised Universal Soil Loss Equation (RUSLE).

Major landuses in the Indian Creek watershed were identified as wheat, grassland, and alfalfa. Harrowing and no tillage were used in the cropland field operations. Crop rotation consisted of wheat, durum, and canola. Planting was done in early April and harvest took place in late August. Fertilizer application consisted of 11-52-0 (Mono Ammonium Phosphate) fertilizer applied in the spring for canola and anhydrous ammonia applied in the fall for wheat and durum.

Climate data was obtained from the North Dakota Agricultural Weather Network (NDAWN) website. Actual climatic data was retrieved from the NDAWN station located in Mott for the years of 2001-2003. Unfortunately the data in 2001 was only available starting in Mid-August. The (Generation of weather Elements for Multiple applications) GEM climatic model provided by the AnnAGNPS model was then utilized to provide synthetic data to supplement the missing NDAWN data prior to August 2001.

As stated above the AnnAGNPS model allows the user to specify which output parameters that are desired for watershed source locations. In the case of the Indian Creek watershed the output data was used to calibrate the BATHTUB model. During the assessment of Indian Creek Dam, the watershed experienced an extended period of no flow events and a flow regime could not be established. The source accounting output data was used to determine the annual accumulation of nutrients and water volume moving through the Indian Creek Dam watershed. The AnnAGNPS model simulation was run for three separate years from 2001-2003. Desired watershed source locations consisted of the inlets (Cell 19, 29, 32, 55, 116, 117 and 174) and outlet (Cell 18) of Indian Creek Dam. When calibrating the BATHTUB model only the inlet (Cell 55) and the outlet (Cell 18) were used because these two cells contained the sampling sites identified in the Quality Assurance Project Plan (QAPP) for the Indian Creek Dam TMDL project. Results of all other output data can be found in Appendix B.

**Table 11. Water volume and nutrient concentrations at outlet cell 18 from 2001-2003.**

| Outlet (Cell 18) | Units | 2001 | 2002 | 2003 | Total | Average |
|---|---|---|---|---|---|---|
| **Water volume** | acre feet | 191.98 | 364.32 | 62.73 | 619.03 | 206.34 |
| **Attached Nitrogen Accumulation** | tons/year | 2.81 | 1.03 | 0.15 | 3.99 | 1.33 |
| **Soluble Nitrogen Accumulation** | tons/year | 7.36 | 7.22 | 2.5 | 17.08 | 5.69 |
| **Attached Phosphorus Accumulation** | tons/year | 0.16 | 0.09 | 0.04 | 0.29 | 0.096 |
| **Soluble Phosphorus Accumulation** | tons/year | 0.76 | 0.47 | 0.24 | 1.47 | 0.49 |

## 5.4 Dissolved Oxygen

Indian Creek Dam is listed as not supporting, fish and aquatic biota uses because of dissolved oxygen levels observed below the North Dakota water quality standard. The North Dakota water quality standard for dissolved oxygen is "not less than 5.0 mg $L^{-1}$". For Indian Creek Dam, low dissolved oxygen levels appear to be related to excessive nutrient loading.

The cycling of nutrients in aquatic ecosystems is largely determined by oxidation-reduction (redox) potential and the distribution of dissolved oxygen and oxygen-demanding particles (Dodds, 2002). Dissolved oxygen gas has a strong affinity for electrons, and thus influences biogeochemical cycling and the biological availability of nutrients to primary producers such as algae. High levels of nutrients can lead to eutrophication, which is defined as the undesirable growth of algae and other aquatic plants. In turn, eutrophication can lead to increased biological oxygen demand and oxygen depletion due to the respiration of microbes that decompose the dead algae and other organic material.

As a result of this direct influence it is anticipated that meeting the phosphorus load reduction target in Indian Creek Dam will address the dissolved oxygen impairment. A reduction in total phosphorus load to Indian Creek Dam would be expected to lower algal biomass levels in the water column thereby reducing the biological oxygen demand exerted by the decomposition of these primary producers. The reduction in biological oxygen demand is therefore assumed to result in attainment of the dissolved oxygen standard.

## 5.5 Sediment

The AnnAGNPS model estimated sediment inflows for Indian Creek Dam (Table 12). The time period over which this amount of storage occurred was 1.00 years, assuming complete retention. Therefore sediment accumulated within the reservoir at an average annual rate of 35,684.11 kg/yr during the years of data collection (2001-2003). This value represents the entire sediment load measured at the inlet (sub-watershed 55), thus assuming 100% retention and a very conservative assumption to further justify delisting of sediment impairments in Indian Creek Dam.

Mulholland and Elwood (1982), state that the average accumulation of sediment within reservoirs is 2 cm/year. Based on a conversion from mass of sediment storage to depth of sediment storage, it can be assumed that Indian Creek Dam is accumulating sediment at a current rate that is considered acceptable for reservoirs.

**Table 12. AnnAGNPS estimated sediment intake for Indian Creek Dam (2001-2003).**

| Total Suspended Solids | Inflow (kg) |
|---|---|
| 2001 | 78,935.96 |
| 2002 | 20,750.94 |
| 2003 | 7,365.43 |
| **Average** | 35,684.11 |

Based on the Mulholland and Elwood (1982) average accumulation rate of 2 cm/yr within reservoirs, a conversion from mass of sediment storage to depth of sediment storage is needed to determine a comparison.

In order to perform the conversion from mass to depth, the particle density of soil is needed. In most mineral soils the average density of particles is in the range of 2.6 to 2.7 $g/cm^3$. This narrow range reflects the predominance of quartz and clay minerals in the soil matrix. Since soils in the Indian Creek Dam watershed are mineral soils, the particle density of silicate minerals can be used to calculate a depth of sediment accumulation within the reservoir. However, for the sake of providing an implicit margin of safety, the low end of the range (2.6 $g/cm^3$) will be used to calculate the equivalent depth of 35,684.11 kg of sediment in Indian Creek Dam.

Based on a sediment loading range of 35,684,110 g/yr times a sediment density of 2.60 $g/cm^3$, the sediment volume deposited in Indian Creek Dam is 92,778,686 $cm^3$ each year.

$$35{,}684{,}110 \text{ g/yr} * (2.60 \text{ g/cm}^3)^{-1} = 13{,}724{,}657.69 \text{ cm}^3\text{/yr}$$

Based on a surface area of 196.3 acres (7,943,979,156.39 $cm^2$), the annual sedimentation rate is 0.00173 cm per year [(13,724,657.69 $cm^3$/yr)/ (7,943,979,156.39 $cm^2$)]. This estimated annual sediment accumulation rate is well below the average sedimentation rate of typical reservoirs.

Further support for the removal of sediment as a pollutant of concern can also be found in literature. As Waters (1995) states, suspended sediment concentrations less than 25 mg $L^{-1}$ is not harmful to fisheries; between 25 and 80 mg $L^{-1}$ reduces fish yield; between 80 and 400 mg $L^{-1}$ is unlikely to display a good fishery; and suspended sediment concentration greater than 400 mg $L^{-1}$ will exhibit a poor fishery. Therefore, research by Waters (1995) supports the view that the mean TSS concentration in Indian Creek Dam of 13.2 mg $L^{-1}$ is not considered harmful to fisheries. While seven samples out of one hundred sixteen exceeded the 25 mg $L^{-1}$ concentration stated by Waters (1995) as reducing fish yield, only two samples exceeded the 80 mg $L^{-1}$ deemed unlikely to display a good fishery. Therefore, it is the recommendation of the TMDL that, in the next North Dakota 303(d) list cycle, Indian Creek Dam should be de-listed for sediment impairments.

Justification for delisting is also based on the Natural Resources Conservation Service (NRCS) Sedimentation Rate Standard for reservoirs. This standard is set at 1/8 inch of sediment eroded from the watershed drainage areas delivered and detained in the sediment pool over the 50-year expected life of the project. Therefore:
Assuming Watershed Area = 10,733 acres = 16.77 $mi^2$
and,
NRCS Sedimentation Rate Standard equals 1/8 inch over 50 yrs
Then,
Watershed Area = 16.77 $mi^2$ = 4.67529480 x $10^8$ $ft^2$;

Sediment Volume = (4.67529480 x $10^8$ $ft^2$ * 1/8 inch)/12 inches = 4,870,100.31 $ft^3$;

Predicted amount of sediment in Indian Creek Dam at 1/8 inch over 50 years =

(4,870,100.31 $ft^3$ * 28,316.8467117 $cm^3$) = 1.379058839 x $10^{11}$ $cm^3$;
Compare this too,
The calculated annual sedimentation rate from observed data entering Indian Creek Dam =
35,684,110 g/yr * (2.60 g/$cm^3$)$^{-1}$ = 13,724,657.69 $cm^3$/yr

Calculated amount of sediment accumulation rate from observed data entering Indian Creek Dam over 50 years
(13,724,657.69 $cm^3$/yr * 50 yrs) = 686,232,884.6 $cm^3$

Using a sedimentation rate standard of 1/8 inch over 50 years, Indian Creek Dam's predicted sediment accumulation rate could be 1.379058839 x $10^{11}$ $cm^3$. When compared with the current sedimentation accumulation rate into the reservoir over 50 years of 686,232,884.6 $cm^3$, Indian Creek Dam appears to be well under the predicted sedimentation rate standard.

## 6.0 MARGIN OF SAFETY AND SEASONALITY

### 6.1 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations require that "TMDLs should be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety (MOS) can either be incorporated into conservative assumptions used to develop the TMDL (implicit) or added as a separate component of the TMDL (explicit).

### 6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and the EPA's regulations require that a TMDL be established with seasonal variations. Indian Creek Dam's TMDL addresses seasonality because the BATHTUB model incorporates seasonal differences in its prediction of annual total phosphorus and nitrogen loadings.

## 7.0 TMDL

The table and sections below summarize the nutrient, sediment, and dissolved oxygen TMDLs for Indian Creek Dam in terms of loading capacity, waste load allocations, load allocations, and a margin of safety. The TMDL can be generically described by the following equation.

TMDL = LC = WLA + LA + MOS

where

LC= loading capacity, or the greatest loading a waterbody can receive without violating water quality standards;

WLA waste load allocation, or the portion of the TMDL allocated to existing or future point sources;

LA load allocation, or the portion of the TMDL allocated to existing or future non-point sources;

MOS margin of safety, or an accounting of the uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of the loading capacity.

### 7.1 Nutrient TMDL

**Table 13. Summary of the Phosphorus TMDL for Indian Creek Dam.**

| Category | Total Phosphorus (kg/yr) | Explanation |
|---|---|---|
| Existing Load | 2,461.2 | From observed data |
| Loading Capacity | 1,230.6 | 50 percent total reduction based on BATHTUB modeling |
| Waste load Allocation | 0.0 | No point sources |
| Load Allocation | 1,107.5 | Entire loading capacity minus MOS is allocated to non-point sources |
| MOS | 123.1 | 10% of the loading capacity (1,230.6 kg/yr) is reserved as an explicit margin of safety |

Based on data collected from 2001 through 2004, the existing load to Indian Creek Dam is estimated at 2,461.2 kg. Assuming a 50% reduction based on BATHTUB and AnnAGNPS modeling results in Indian Creek Dam reaching a TMDL target total phosphorus concentration of 0.031 mg $L^{-1}$, then the TMDL or Loading Capacity is 1,230.6 kg. Assuming 10% of the (1,230.6 kg/yr) is assigned to the MOS and there are no point sources in the watershed, all of the remaining loading capacity (1,107.5 kg/yr) is assigned to the load allocation.

### 7.2 Sediment TMDL

No reduction necessary, delist for sediment.

### 7.3 Dissolved Oxygen TMDL

AnnAGNPS and BATHTUB models indicate that excessive nutrient loading is responsible for the low dissolved oxygen levels in Indian Creek Dam. Wetzel (1983) summarized, “The loading of organic matter to the hypolimnion and sediments of productive eutrophic lakes increases the consumption of dissolved oxygen. As a result, the oxygen content of the hypolimnion is reduced progressively during the period of summer stratification.”

Carpenter et al. (1998), has shown that nonpoint sources of phosphorous has lead to eutrophic conditions for many lake/reservoirs across the U.S. One consequence of eutrophication is oxygen depletions caused by decomposition of algae and aquatic plants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment of designated beneficial uses. However, the rates of recovery are variable among lakes/reservoirs. This supports the Department of Health's viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels, the concern is that this process takes a significant amount of time (5-15 years).

In Lake Erie, heavy loadings of phosphorous have impacted the lake severely. Monitoring and research from the 1960's has shown that depressed hypolimnetic dissolved oxygen levels were responsible for large fish kills and large mats of decaying algae. Binational programs to reduce nutrients into the lake have resulted in a downward trend of the oxygen depletion rate since monitoring began in the 1970's. The trend of oxygen depletion has lagged behind that of phosphorous reduction, but this was expected (See: http://www.epa.gov/glnpo/lakeerie/dostory.html).

Nürnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify responses to watershed restoration measures which make it very useful for TMDL development. Nürnberg (1996) developed several regression models that show nutrients control all trophic state indicators related to oxygen and phytoplankton in lakes/reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. NDDoH has calculated the morphometric parameters such as surface area ($A_o$ = 196.3 acres; 0.794 $km^2$), mean depth (z = 12.3 feet; 3.74 meters), and the ratio of mean depth to surface area ($z/A_o^{0.5}$ = 0.88) for Indian Creek Dam, which show that these parameters are within the range of lakes used by Nürnberg. Based on this information, NDDoH is confident that Nürnberg's empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs. NDDoH is also confident that prescribed BMPs will reduce external loading of nutrients to the Dam which will reduce algae blooms and therefore increase oxygen levels over time.

Best professional judgment concludes that as levels of phosphorus are reduced by the implementation of best management practices, dissolved oxygen levels will improve. This is supported by the research of Thornton, et al (1990). They state that, "... as organic deposits were exhausted, oxygen conditions improved." To insure that the implementation of BMPs will reduce phosphorus levels and result in a corresponding increase in dissolved oxygen, water quality monitoring will be conducted in accordance with an approved Quality Assurance Project Plan.

## 8.0 ALLOCATION

This TMDL will be implemented by several parties on a volunteer basis. Phosphorus loads into the reservoir will be reduced by 50 % through treating of the AnnAGNPS identified critical areas (Figure 12). There are 99 cells within the Indian Creek Dam watershed ranging in size from 1 to 120 acres that were identified as "critical" by AnnAGNPS modeling. Critical areas in the watershed appear green, and were valued at .10-.77% phosphorus as a percentage of total phosphorus. Highly critical areas are distinguished by red cells valued at .78-3.1% phosphorus as a percentage of total phosphorus. These cells represent a total area of 2,024.89 (cropland) and 124.94 (pasture/rangeland) acres, or 20% of the entire watershed. If the watershed critical areas can be treated with BMPs like CRP, no-till, nutrient management systems, grazing systems, etc., then the specified reduction is possible. Also, by effectively utilizing hypolimnetic withdrawal techniques according to recommendations from the NDDoH and the North Dakota Game and Fish Department, there will be an additional phosphorus load reduction and possible added improvement in dissolved oxygen levels during the winter.

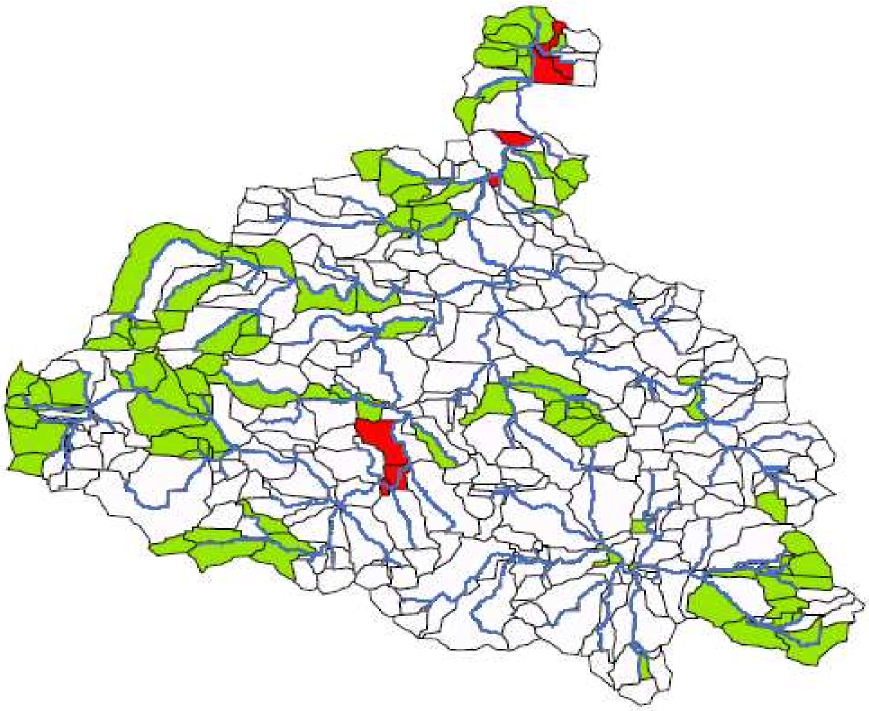

**Figure 12. AnnAGNPS Identification of Critical Areas for BMP Implementation.**

## 9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a hard copy of the TMDL for Indian Creek Dam and a request for comment has been mailed to participating agencies, partners, and to those who request a copy. Those included in the mailing of a hard copy are as follows:

- Hettinger County Soil Conservation District
- Hettinger County Water Resource Board
- Natural Resource Conservation Service (Hettinger County Field Office)
- Environmental Protection Agency
- U.S. Fish & Wildlife Service

In addition to mailing copies of this TMDL for Indian Creek Dam to interested parties, the TMDL has been posted on the North Dakota Department of Health, Division of Water Quality web site at http://www.health.state.nd.us/wq/. A 30 day public notice soliciting comment and participation has also been published in the following newspapers:

- The Herald, Published…
- Dickinson Press, Published…
- Bismarck Tribune, Published…

## 10.0 MONITORING

To insure that the implementation of BMPs will reduce phosphorus levels and result in a corresponding increase in dissolved oxygen, water quality monitoring will be conducted in accordance with an approved Quality Assurance Project Plan (QAPP).

Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. These include, but are not limited to nutrients (i.e., nitrogen and phosphorus) and dissolved oxygen. Once a watershed restoration plan (e.g. 319 PIP) is implemented, monitoring will be conducted in the lake/reservoir beginning two years after implementation and extending 5 years after the implementation project is complete.

## 11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds or other watershed restoration programs (e.g. USDA EQIP), as well as securing a local project sponsor and the required matching funds. Provided these three requirements are in place, a project implementation plan (PIP) is developed in accordance with the TMDL and submitted to the ND Nonpoint Source Pollution Task Force and US EPA for approval. The implementation of the best management practices contained in the NPS pollution management project is voluntary. Therefore, success of any TMDL implementation project is ultimately dependent on the ability of the local project sponsor to find cooperating producers.

Monitoring is an important and required component of any PIP. As a part of the PIP, data are collected to monitor and track the effects of BMP implementation as well as to judge overall project success. Quality Assurance Project Plans (QAPPs) detail the strategy of how, when and where monitoring will be conducted to gather the data needed to document the TMDL implementation goal(s). As data are gathered and analyzed, watershed restoration tasks are adapted to place BMPs where they will have the greatest benefit to water quality.

## 12.0 ENDANGERED SPECIES ACT COMPLIANCE

States are encouraged to participate with the U.S. Fish and Wildlife Service and EPA in documenting threatened and endangered species on the Endangered Species List. In an effort to assist in Endangered Species Act compliance, a request for a list of endangered and/or threatened species was made to the U.S. Fish and Wildlife Service (Figures 13 and 14). A hard copy of the draft TMDL report will also be sent to the U.S. Fish and Wildlife Services Bismarck, North Dakota office for review. The following is a list of threatened or endangered species specific to Indian Creek Dam and Hettinger County.

- Whooping crane (Grus Americana), Endangered
- Black-footed ferret (Mustela nigripes), Endangered
- Bald eagle (Haliaeetus leucocephalus), Threatened

U.S. Fish & Wildlife Service
3425 Miriam Avenue
Bismarck, North Dakota 58501

OFFICE TRANSMITTAL

To: Paul Keeney
Regional TMDL/Watershed Liaison
Division of Water Quality
ND Department of Health
Bismarck, ND

☐ Action

☒ Information

From: Kevin Johnson    Division: Ecological Services    Date: 5-5-06

As requested in your letter of April 24, 2006, enclosed find a list of the threatened and endangered species and designated critical habitat for the counties of Grant, Hettinger and Williams. These lists are to help in your development of Total Maximum Daily Loads for several watersheds in western and southwestern North Dakota.

If you need anything else, please feel free to give us a call.

RECEIVED
MAY 08 2006
DIV. OF WATER QUALITY

**Figure 13. Office Transmittal Received from U.S. Fish & Wildlife Service.**

FEDERAL THREATENED AND ENDANGERED SPECIES
FOUND IN HETTINGER COUNTY
NORTH DAKOTA
May 2006

**ENDANGERED SPECIES**

Birds

Whooping crane (Grus Americana): Migrates through west and central counties during spring and fall. Prefers to roost on wetlands and stockdams with good visibility. Young adult summered in North Dakota in 1989, 1990, and 1993. Total population 140-150 birds.

Mammals

Black-footed ferret (Mustela nigripes): Exclusively associated with prairie dog towns. No records of occurrence in recent years, although there is potential for reintroduction in the future.

**THREATENED SPECIES**

Birds

Bald eagle (Haliaeetus leucocephalus): Migrates spring and fall statewide but primarily along the major river courses. It concentrates along the Missouri River during winter and is known to nest in the floodplain forest.

**Figure 14. Threatened and Endangered Species List and Designated Critical Habitat.**

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# Appendix A

**A Calibrated Trophic Response Model (Bathtub) for Indian Creek Dam**
**As a Tool to Evaluate Various Nutrient Reduction Alternatives**
**Based on Anne-AGNPS Modeling and Data Collected by the Hettinger County Soil Conservation District from**
**October 16, 2001 through February 16, 2005**
**Prepared by**
**Peter Wax**
**July 11, 2006**

## Introduction

In order to meet the project goals, as set forth by the project sponsors of identifying possible options to improve the trophic condition of Indian Creek Dam to levels capable of maintaining the reservoirs beneficial uses (e.g., fishing, recreation, and drinking water supply), and the objectives of this project, which are to: (1) develop a nutrient and sediment budget for the reservoir; (2) identify the primary sources and causes of nutrients and sediments to the reservoir; and (3) examine and make recommendations for reservoir restoration measures which will reduce documented nutrient and sediment loadings to the reservoir, a calibrated trophic response model was developed for Indian Creek Dam. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Indian Creek Dam's trophic status. The model will allow resource managers and the public to relate changes in nutrient loadings to the trophic condition of the reservoir and to set realistic lake restoration goals that are scientifically defensible, achievable and socially acceptable.

### Methods

For purposes of this project, the BATHTUB program was use to predict changes in trophic status based on changes in nutrient loading. The BATHTUB program, developed by the US Army Corps of Engineers Waterways Experiment Station (Walker 1996), applies an empirically derived eutrophication model to reservoirs. The model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project are summarized, or reduced, in a format which can serve as inputs to the model. The following is a brief explanation of the computer software, methods, and procedures used to complete each of these phases.

### Tributary Data

Watershed hydraulic and pollutant loads were estimated using actual water quality data and the annualized agricultural nonpoint source (AnnAGNPS) model. The AnnAGNPS model was developed by the US Department of Agriculture's Agriculrural Research Services to model relative quantity and quality of outflow from a watershed in order to assess there pollution potential.

The AnnAGNPS model identified six subwatersheds entering Indian Creek dam ranging in size from 0.11 to 13.06 square kilometers for a total watershed size 37.57 square kilometers including the lake surface. Model outputs include hydraulic, and soluble and sediment attached nutrient loads from each subwatershed as well as the lake outlet. Since the bathtub model also requires the load of total nitrogen and total phosphorus these were calculated as a ratio the soluble load. The ratios were calculated from 42 inlet samples and 74 outlet samples collected between October 16, 2001 and February 16, 2005. These data were then provided as an input data to calibrate the BATHTUB eutrophication response model.

## Lake Data

Indian Creek Dam's in-lake water quality data was reduced using Microsoft Excel. The data was reduced in excel to provide three computational functions, including: (1) the ability to display constitute concentrations as a function of depth, location, and/or date; (2) calculate summary statistics (e.g., mean, median and standard error in the mixed layer of the lake or reservoir); and (3) track the temporal trophic status. The Excel program output data is used as input to calibrate the BATHTUB model.

## Bathtub Model Calibration

As stated previously, the BATHTUB eutrophication model was selected for this project as a means of evaluating the effects of various nutrient reduction alternatives on the predicted trophic status of Indian Creek Dam. BATHTUB performs water and nutrient balance calculations in a steady-state. The BATHTUB model also allows the user to spatially segment the reservoir. Eutrophication related water quality variables (e.g., total phosphorus, total nitrogen, chlorophyll-*a*, secchi depth, organic nitrogen, orthophosphorous, and hypolimnetic oxygen depletion rate) are predicted using empirical relationships previously developed and tested for reservoir systems (Walker 1985).

Within the BATHTUB program the user can select from six schemes based on reservoir morphometry and the needs of the resource manager. Using BATHTUB the user can view the reservoir as a single spatially averaged reservoir or as single segmented reservoir. The user can also model parts of the reservoir, such as an embayment, or model a collection of reservoirs. For purposes of this project, Indian Creek Dam was modeled as a single, spatially averaged, reservoir.

Once input is provided to the model from FLUX and Excel the user can compare predicted conditions (i.e., model output) to actual conditions. Since BATHTUB uses a set of generalized rates and factors, predicted vs. actual conditions may differ by a factor of 2 or more using the initial, un-calibrated, model. These differences reflect a combination of measurement errors in the inflow and outflow data, as well as unique features of the reservoir being modeled.

In order to closely match an actual in-lake condition with the predicted condition, BATHTUB allows the user to modify a set of calibration factors (Table 1). For a complete description of the BATHTUB model the reader is referred to Walker (1996).

Table 1. Selected model parameters, number and name of model, and where appropriate the calibration factor used for Indian Creek Dam Bathtub Model.

| Model Option | Model Selection | Calibration Factor |
| --- | --- | --- |
| Conservative Substance | 0 Not Computed | 1.00 |
| Phosphorus Balance | 2 2nd Order, Decay | 0.98 |
| Phosphorus – Ortho P | 2 | 0.85 |
| Nitrogen Balance | 5 Buchman Flushing | 1.01 |
| Organic Nitrogen | 5 | 2.70 |
| Chlorophyll-a | 1 P, N, Low Turbidity | 0.75 |
| Secchi Depth | 1 Vs. Chla & Turbidity | 1.00 |
| Phosphorus Calibration | 2 Concentrations | NA |
| Nitrogen Calibration | 2 Concentrations | NA |
| Availability Factors | 0 ignore | NA |
| Mass-Balance Tables | 0 Use Observed Concentrations | NA |

**Results**

The trophic response model, BATHTUB, has been calibrated to match Indian Creek Dam's trophic response for the project period between October 16th, 2001 to Fenruary 16 2005. This is accomplished by combining AnnAGNPS annualized loading estimates for the hydrologic years 2001, 2002 and 2003 with in-lake water quality collected between October 16th, 2001 to Fenruary 16 2005.

Hydraulic and pollutant load for the project period is estimated by the USDA, ARS AnnAGNPS model and the corresponding in-lake water quality data are reduced utilizing Excel. The output from these two programs is then provided as input to the BATHTUB model. The model is calibrated through several iterations, first by selecting appropriate empirical relationships for model coefficients (e.g., nitrogen and phosphorus sedimentation, nitrogen and phosphorus decay, oxygen depletion, and algal/chlorophyll growth), and second by adjusting model calibration factors for those coefficients (Table 1). The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates made from project monitoring data.

The two primary nutrients controlling trophic response in Indian Creek Dam are nitrogen and phosphorus. After calibration the observed average annual concentration of total nitrogen and total phosphorus compare well with those of the BATHTUB model. The model predicts that the reservoir has a three-year volume-weighted mean total phosphorus concentration of 0.0499 mg $L^{-1}$ and a three-year volume-weighted total nitrogen concentration of 1.690 mg $L^{-1}$ compared to observed values for total phosphorus and total nitrogen of 0.050 mg $L^{-1}$ and 1.690 mg $L^{-1}$, respectively (Table 2).

Other measures of trophic response predicted by the model are average annual chlorophyll-a concentration and average secchi disk transparency. The calibrated model did just as good a job of predicting average chlorophyll-a concentration and secchi disk transparency within the reservoir as total phosphorus and total nitrogen (Table 2).

Once predictions of total phosphorus, chlorophyll-a, and secchi disk transparency are made, the model calculates Carlson's Trophic Status Index (TSI) (Carlson 1977) as a means of expressing predicted trophic response (Table 2). Carlson's TSI is an index that can be used to measure the relative trophic state of a lake or reservoir. Simply stated, trophic state is how much production (i.e., algal and weed growth) occurs in the waterbody. The lower the nutrient concentrations are within the waterbody the lower the production and the lower the trophic state or level. In contrast, increased nutrient concentrations in a lake or reservoir increase the production of algae and weeds which make the lake or reservoir more eutrophic or of a higher trophic state. Oligotrophic is the term which describes the least productive lakes and hypereutrophic is the term used to describe lakes and reservoirs with excessive nutrients and primary production.

Table 2. Observed and Predicted Values for Selected Trophic Response Variables for the Calibrated "BATHTUB" Model.

| | Value | |
|---|---|---|
| Variable | Observed | Predicted |
| Total Phosphorus as P (mg/L) | 0.050 | 0.0499 |
| Total Dissolved Phosphorus (mg/L) | 0.020 | 0.0199 |
| Total Nitrogen as N (mg/L) | 1.690 | 1.690 |
| Organic Nitrogen as N (mg/L) | 1.630 | 1.607 |
| Chlorophyll-a ($\mu$g/L) | 17.97 | 18.24 |
| Secchi Disk Transparency (meters) | 1.34 | 1.33 |
| Carlson's TSI for Phosphorus | 60.56 | 60.54 |
| Carlson's TSI for Chlorophyll-a | 58.94 | 59.08 |
| Carlson's TSI for Secchi Disk | 55.78 | 55.91 |

Figure 1 provides a graphic summary of the TSI range for each trophic level compared to values for each of the trophic response variables. The calibrated model provided predictions of trophic status which are similar to the observed TSI values for the project period (Table 2). Over all the predicted and observed TSI values for phosphorus, chlorophyll and secchi disk suggest Indian Creek Dam is eutrophic. Figure 2 is a graphic that shows the annual temporal distribution of Indian Creek Dam's trophic state based on the three parameters total phosphorus as phosphate, and chlorophyll-a concentrations and secchi disk depth transparency.

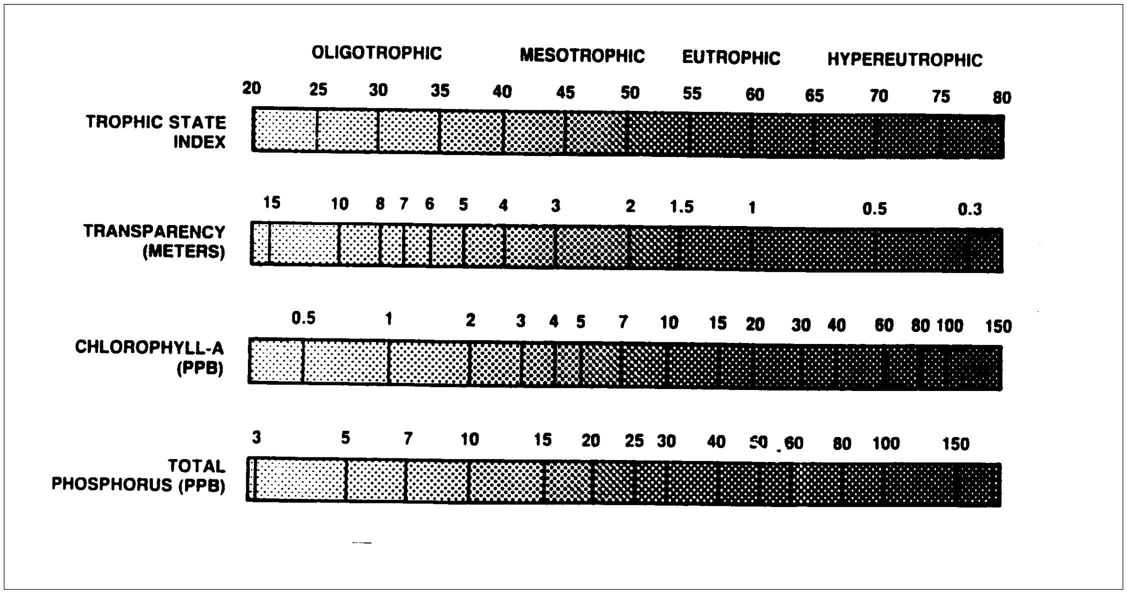



Figure 1. Graphic depiction of Carlson's Trophic Status Index

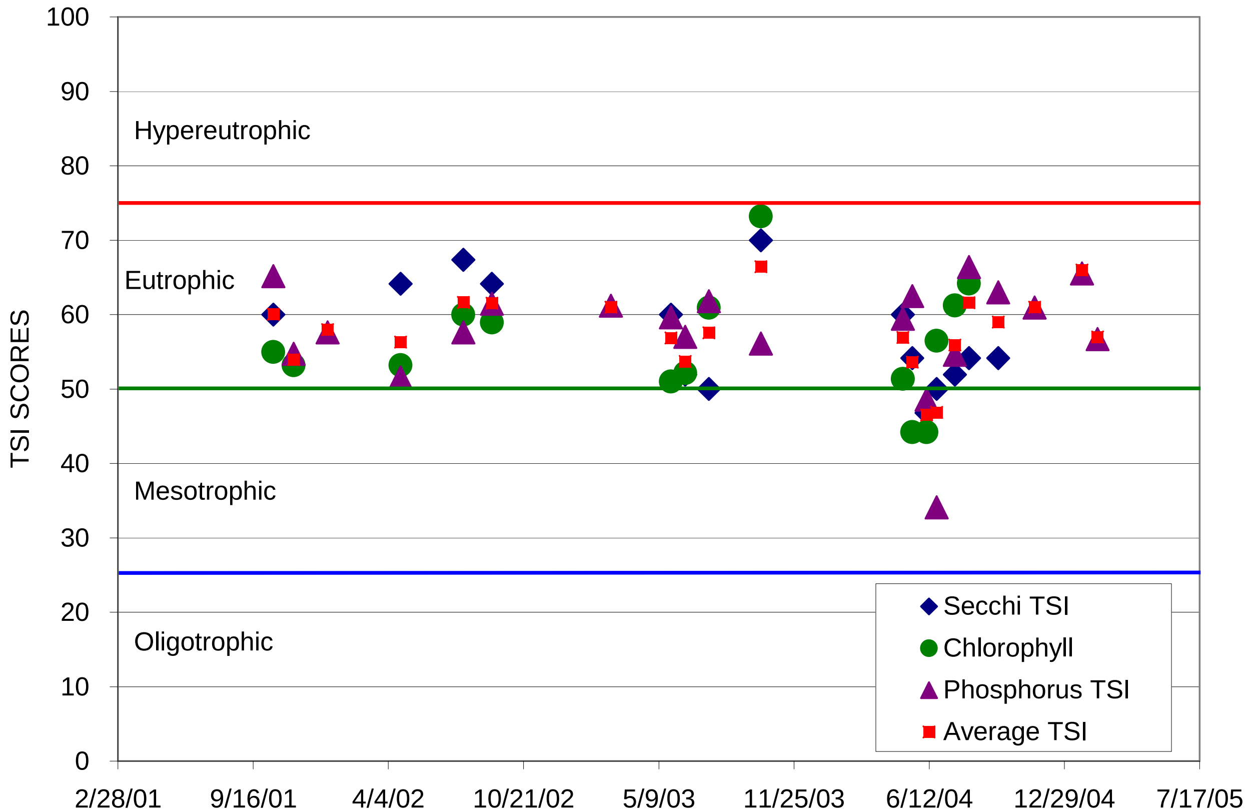



Figure 2. Temporal distribution of Carlosn's Trophic Status Index scores for Indian Creek Dam (10/16/2001 – 2/16/2005)

Model Predictions

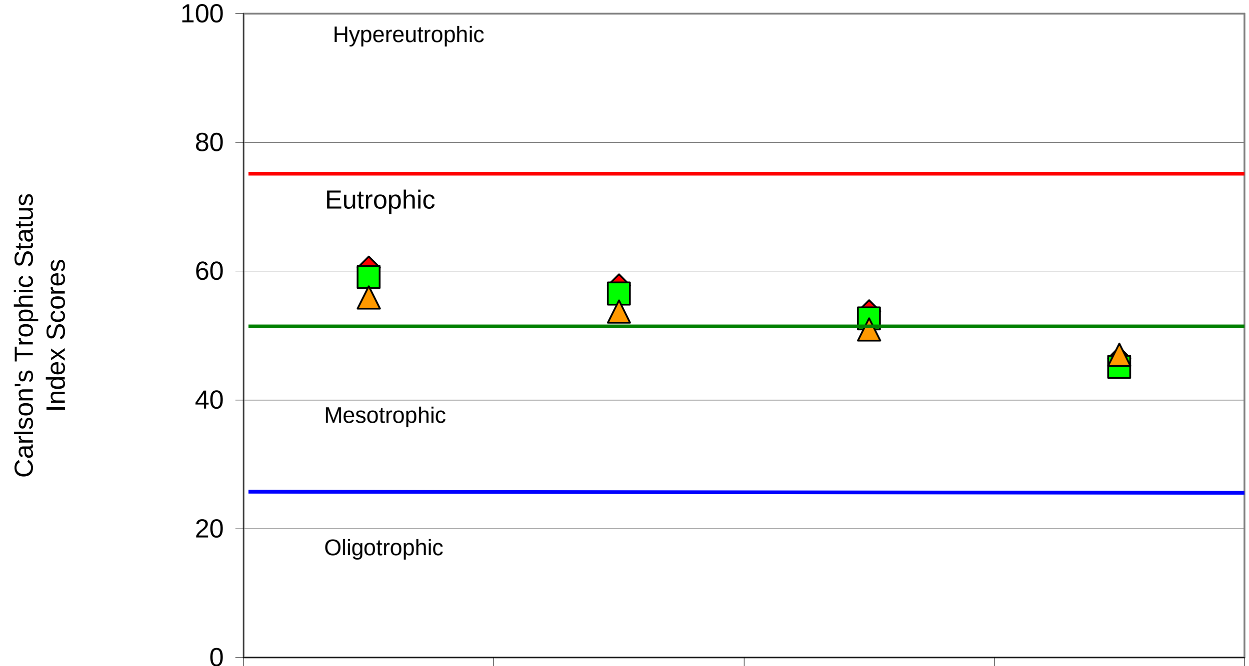
Once the model is calibrated to existing conditions, the model can be used to evaluate the effectiveness of any number of nutrient reduction or lake restoration alternatives. This evaluation is accomplished comparing predicted trophic state, as reflected by Carlson's TSI, with currently observed TSI values. Modeled nutrient reduction alternatives are presented in three basic categories: (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads. For Indian Creek Dam only external nutrient loads were addressed. External nutrient loads were addressed because they are known to cause eutrophication and because they are controllable through the implementation of watershed Best Management Practices (BMPs).

Predicted changes in trophic response to Indian Creek Dam were evaluated by reducing externally derived phosphorus loads by 25, 50, and 75 percent. These reductions were simulated in the model by reducing the phosphorus and nitrogen concentrations in the contributing tributary and other external delivery sources by 25, 50, and 75 percent. Since there is no reliable means of estimating how much hydraulic discharge would be reduced through the implementation of BMPs, flow was held constant.

The model results indicate that if it were possible to reduce external phosphorus loading to Indian Creek Dam by 50 percent the average annual total phosphorus concentrations in the lake would decrease significantly (Table 3, Figure 3). With a 50 percent reduction in external phosphorus and nitrogen load, the model predicts a reduction in Carlson's TSI score from 60.54 to 53.75 for total phosphorus, 58.94 to 52.66 for chlorophyll-a, and from 55.78 to 50..96 for secchi disk transparency, corresponding to a trophic response from state of eutrophic to borderline mesotrophic.

Table 3. Calibrated model, and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

| | | Predicted | | |
|---|---|---|---|---|
| Variable | Calibrated | 25 % | 50 % | 75 % |
| Total Phosphorus as P (mg/L) | 0.050 | 0.041 | 0.031 | 0.019 |
| Total Dissolved Phosphorus (mg/L) | 0.020 | 0.017 | 0.014 | 0.010 |
| Total Nitrogen as N (mg/L) | 1.690 | 1.274 | 0.858 | 0.442 |
| Chlorophyll-a ($\mu$g/L) | 18.24 | 14.03 | 9.47 | 4.39 |
| Secchi Disk Transparency (meters) | 1.34 | 1.54 | 1.87 | 2.46 |
| Carlson's TSI for Phosphorus | 60.54 | 57.78 | 53.75 | 46.47 |
| Carlson's TSI for Chlorophyll-a | 58.94 | 56.51 | 52.66 | 45.11 |
| Carlson's TSI for Secchi Disk | 55.78 | 53.74 | 50.96 | 47.05 |




| | Calibrated | Less 25% | Less 50% | Less 75% |
|---|---|---|---|---|
| TSI-Phosphorus | 60.54 | 57.78 | 53.75 | 46.47 |
| TSI-Chlorophyll-a | 59.08 | 56.51 | 52.66 | 45.11 |
| TSI-Secchi | 55.91 | 53.74 | 50.96 | 47.04 |

**Figure 3. Predicted trophic response to phosphorus load reductions to Indian Creek Dam of 25, 50, and 75 Percent.**

# Appendix B
## AnnAGNPS Model Data

2001

```
Totals at Outlet:
          Simulation Days           365
          Drainage Area       10733.931

Outlet               Y Y Y Y Y N         Y          10733.93  10733.93
          Water                                     228.2935
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    79.976    57.470     1.170       0.0       0.0
          Size Total    79.976    57.470     1.170       0.0       0.0
          Source Tot       0.0       0.0   138.616   138.616
          Nutrients       2.81      7.36      1.39       0.0      0.23      1.14

18        Upstream   Y Y Y Y Y N         Y           9231.22   9231.22
          Water                                     191.9862
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    66.130    80.926     1.419       0.0       0.0
          Size Total    66.130    80.926     1.419       0.0       0.0
          Source Tot       0.0       0.0   148.475   148.475
          Nutrients       2.14      5.96      1.05       0.0      0.16      0.76

19        Upstream   Y Y Y Y Y N         Y            431.24    472.75
          Water                                       3.5461
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     3.613     5.901     1.276       0.0       0.0
          Size Total     3.613     5.901     1.276       0.0       0.0
          Source Tot       0.0       0.0    10.790    10.790
          Nutrients       0.09      0.09      0.04       0.0  0.20E-02  0.63E-02

29        Upstream   Y Y Y Y Y N         Y             23.25     26.06
          Water                                       1.5021
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     0.259     0.118     0.047       0.0       0.0
          Size Total     0.259     0.118     0.047       0.0       0.0
          Source Tot       0.0       0.0     0.424     0.424
          Nutrients   0.30E-02      0.02  0.13E-02       0.0  0.34E-04  0.19E-02

32        Upstream   Y Y Y Y Y N         Y            949.15   1095.66
          Water                                      10.8739
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     6.553     9.456     0.526       0.0       0.0
          Size Total     6.553     9.456     0.526       0.0       0.0
          Source Tot       0.0       0.0    16.535    16.535
          Nutrients       0.14      0.22      0.07       0.0  0.56E-02      0.02

55        Upstream   Y Y Y Y Y N         Y           3040.76   3129.89
          Water                                      54.1464
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    28.223    51.603     7.186       0.0       0.0
          Size Total    28.223    51.603     7.186       0.0       0.0
```

```
          Source Tot       0.0       0.0    87.012    87.012
          Nutrients       0.73      1.70      0.34       0.0      0.04      0.20

116       Upstream   Y Y Y Y Y N         Y               22.41     33.01
          Water                                       0.0016
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     0.212     0.518     0.065       0.0       0.0
          Size Total     0.212     0.518     0.065       0.0       0.0
          Source Tot       0.0       0.0     0.794     0.794
          Nutrients   0.18E-02  0.25E-03  0.78E-03       0.0  0.20E-04  0.57E-04

117       Upstream   Y Y Y Y Y N         Y             3207.70   3207.70
          Water                                      70.8736
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    20.290    29.634     0.272       0.0       0.0
          Size Total    20.290    29.634     0.272       0.0       0.0
          Source Tot       0.0       0.0    50.196    50.196
          Nutrients       0.83      2.60      0.42       0.0      0.07      0.40

174       Upstream   Y Y Y Y Y N         Y              958.62    989.44
          Water                                      32.1073
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    11.696    19.784     3.918       0.0       0.0
          Size Total    11.696    19.784     3.918       0.0       0.0
          Source Tot       0.0       0.0    35.398    35.398
          Nutrients       0.51      1.09      0.25       0.0      0.03      0.15
```

2002

```
Totals at Outlet:
          Simulation Days             365
          Drainage Area         10733.931

Outlet               Y Y Y Y Y N         Y            10733.93  10733.93
          Water                                     427.2376
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    29.748    26.794     0.241       0.0       0.0
          Size Total    29.748    26.794     0.241       0.0       0.0
          Source Tot       0.0       0.0    56.784    56.784
          Nutrients       1.41      9.41      0.74       0.0      0.14      0.69

18        Upstream   Y Y Y Y Y N         Y             9231.22   9231.22
          Water                                     364.3287
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill    24.062    29.355     0.233       0.0       0.0
          Size Total    24.062    29.355     0.233       0.0       0.0
          Source Tot       0.0       0.0    53.650    53.650
          Nutrients       1.03      7.22      0.55       0.0      0.09      0.47

19        Upstream   Y Y Y Y Y N         Y              431.24    472.75
          Water                                      12.8179
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 1.052 | 1.771 | 0.028 | 0.0 | 0.0 | |
| | Size Total | 1.052 | 1.771 | 0.028 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 2.850 | 2.850 | | |
| | Nutrients | 0.02 | 0.13 | 0.01 | 0.0 | 0.75E-03 | 0.31E-02 |
| 29 | Upstream | Y Y Y Y Y N | | Y | 23.25 | 26.06 | |
| | Water | | | | 2.4379 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 0.159 | 0.074 | 0.031 | 0.0 | 0.0 | |
| | Size Total | 0.159 | 0.074 | 0.031 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 0.264 | 0.264 | | |
| | Nutrients | 0.18E-02 | 0.02 | 0.81E-03 | 0.0 | 0.21E-04 | 0.14E-02 |
| 32 | Upstream | Y Y Y Y Y N | | Y | 949.15 | 1095.66 | |
| | Water | | | | 30.3254 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 1.780 | 2.797 | 0.317 | 0.0 | 0.0 | |
| | Size Total | 1.780 | 2.797 | 0.317 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 4.894 | 4.894 | | |
| | Nutrients | 0.11 | 0.54 | 0.06 | 0.0 | 0.48E-02 | 0.02 |
| 55 | Upstream | Y Y Y Y Y N | | Y | 3040.76 | 3129.89 | |
| | Water | | | | 108.9848 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 8.246 | 13.651 | 0.977 | 0.0 | 0.0 | |
| | Size Total | 8.246 | 13.651 | 0.977 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 22.874 | 22.874 | | |
| | Nutrients | 0.33 | 2.08 | 0.17 | 0.0 | 0.02 | 0.12 |
| 116 | Upstream | Y Y Y Y Y N | | Y | 22.41 | 33.01 | |
| | Water | | | | 0.2996 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 0.099 | 0.243 | 0.0 | 0.0 | 0.0 | |
| | Size Total | 0.099 | 0.243 | 0.0 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 0.343 | 0.343 | | |
| | Nutrients | 0.83E-03 | 0.27E-02 | 0.37E-03 | 0.0 | 0.93E-05 | 0.61E-04 |
| 117 | Upstream | Y Y Y Y Y N | | Y | 3207.70 | 3207.70 | |
| | Water | | | | 134.9697 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 7.578 | 9.884 | 0.434 | 0.0 | 0.0 | |
| | Size Total | 7.578 | 9.884 | 0.434 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 17.896 | 17.896 | | |
| | Nutrients | 0.38 | 3.08 | 0.21 | 0.0 | 0.05 | 0.25 |
| 174 | Upstream | Y Y Y Y Y N | | Y | 958.62 | 989.44 | |
| | Water | | | | 43.4783 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 3.865 | 5.724 | 0.049 | 0.0 | 0.0 | |
| | Size Total | 3.865 | 5.724 | 0.049 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 9.639 | 9.639 | | |
| | Nutrients | 0.18 | 1.17 | 0.09 | 0.0 | 0.02 | 0.09 |

2003

```
Totals at Outlet:
          Simulation Days           365
          Drainage Area       10733.931

Outlet              Y Y Y Y Y N         Y          10733.93  10733.93
          Water                                     76.5432
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     8.374     2.189     0.051       0.0       0.0
          Size Total     8.374     2.189     0.051       0.0       0.0
          Source Tot       0.0       0.0    10.614    10.614
          Nutrients       0.19      3.11      0.09       0.0      0.07      0.38

18        Upstream  Y Y Y Y Y N         Y           9231.22   9231.22
          Water                                     62.7361
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     6.968     5.604     0.058       0.0       0.0
          Size Total     6.968     5.604     0.058       0.0       0.0
          Source Tot       0.0       0.0    12.630    12.630
          Nutrients       0.15      2.50      0.07       0.0      0.04      0.24

19        Upstream  Y Y Y Y Y N         Y            431.24    472.75
          Water                                      1.0313
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     0.336     0.370     0.035       0.0       0.0
          Size Total     0.336     0.370     0.035       0.0       0.0
          Source Tot       0.0       0.0     0.741     0.741
          Nutrients   0.71E-02      0.07  0.31E-02       0.0  0.68E-03  0.36E-02

29        Upstream  Y Y Y Y Y N         Y             23.25     26.06
          Water                                      0.6992
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     0.045     0.019     0.005       0.0       0.0
          Size Total     0.045     0.019     0.005       0.0       0.0
          Source Tot       0.0       0.0     0.070     0.070
          Nutrients   0.52E-03      0.01  0.23E-03       0.0  0.59E-05  0.60E-03

32        Upstream  Y Y Y Y Y N         Y            949.15   1095.66
          Water                                      3.2357
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     0.725     0.599     0.064       0.0       0.0
          Size Total     0.725     0.599     0.064       0.0       0.0
          Source Tot       0.0       0.0     1.387     1.387
          Nutrients       0.01      0.16  0.48E-02       0.0  0.19E-02      0.01

55        Upstream  Y Y Y Y Y N         Y           3040.76   3129.89
          Water                                     16.4401
          Bed & Bank       0.0       0.0       0.0       0.0       0.0
          Gully            0.0       0.0       0.0       0.0       0.0
          Sheet&Rill     2.649     4.821     0.649       0.0       0.0
          Size Total     2.649     4.821     0.649       0.0       0.0
          Source Tot       0.0       0.0     8.119     8.119
          Nutrients       0.06      0.76      0.03       0.0      0.01      0.06
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 116 | Upstream | Y Y Y Y Y N | Y | | 22.41 | 33.01 | |
| | Water | | | | 0.0 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Size Total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 0.0 | 0.0 | | |
| | Nutrients | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 117 | Upstream | Y Y Y Y Y N | Y | | 3207.70 | 3207.70 | |
| | Water | | | | 22.4872 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 1.899 | 2.439 | 0.010 | 0.0 | 0.0 | |
| | Size Total | 1.899 | 2.439 | 0.010 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 4.348 | 4.348 | | |
| | Nutrients | 0.05 | 1.08 | 0.02 | 0.0 | 0.02 | 0.12 |
| 174 | Upstream | Y Y Y Y Y N | Y | | 958.62 | 989.44 | |
| | Water | | | | 10.0687 | | |
| | Bed & Bank | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Gully | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | Sheet&Rill | 0.881 | 1.731 | 0.174 | 0.0 | 0.0 | |
| | Size Total | 0.881 | 1.731 | 0.174 | 0.0 | 0.0 | |
| | Source Tot | 0.0 | 0.0 | 2.785 | 2.785 | | |
| | Nutrients | 0.02 | 0.32 | 0.78E-02 | 0.0 | 0.73E-02 | 0.04 |

# Appendix C
## Dissolved Oxygen and Temperature Raw Data

**Dissolved Oxygen and Temperature Raw Data Table**

| Site # | Date | Depth (m) | Temp | DO |
|---|---|---|---|---|
| 380765 | 10/16/2001 | 0.5 | 7.71 | 10.86 |
| 380765 | 10/16/2001 | 1 | 7.69 | 10.73 |
| 380765 | 10/16/2001 | 2 | 7.69 | 10.70 |
| 380765 | 10/16/2001 | 3 | 7.69 | 10.70 |
| 380765 | 10/16/2001 | 4 | 7.68 | 10.67 |
| 380765 | 10/16/2001 | 5 | 7.70 | 10.56 |
| | | | | |
| 380765 | 11/15/2001 | 0.5 | 5.6 | 11.8 |
| 380765 | 11/15/2001 | 1 | 4.9 | 11.14 |
| 380765 | 11/15/2001 | 2 | 4.8 | 11.03 |
| 380765 | 11/15/2001 | 3 | 4.8 | 10.83 |
| 380765 | 11/15/2001 | 4 | 4.7 | 10.71 |
| 380765 | 11/15/2001 | 5 | 4.7 | 10.57 |
| 380765 | 11/15/2001 | 6 | 4.7 | 10.58 |
| 380765 | 11/15/2001 | 7 | 4.7 | 10.53 |
| | | | | |
| 380765 | 01/04/2002 | 0.5 | 2.3 | 12.88 |
| 380765 | 01/04/2002 | 1 | 2.4 | 12.87 |
| 380765 | 01/04/2002 | 2 | 2.4 | 12.91 |
| 380765 | 01/04/2002 | 3 | 2.4 | 12.98 |
| 380765 | 01/04/2002 | 4 | 2.8 | 11.70 |
| 380765 | 01/04/2002 | 5 | 3.2 | 9.98 |
| 380765 | 01/04/2002 | 6 | 3.2 | 9.55 |
| 380765 | 01/04/2002 | 7 | 2.7 | 11.90 |
| 380765 | 01/04/2002 | 7.5 | 2.8 | 11.65 |
| | | | | |
| 380765 | 04/22/2002 | 0.5 | 7.6 | 10.83 |
| 380765 | 04/22/2002 | 1 | 7.5 | 10.72 |
| 380765 | 04/22/2002 | 2 | 7.5 | 10.62 |
| 380765 | 04/22/2002 | 3 | 7.5 | 10.50 |
| 380765 | 04/22/2002 | 4 | 7.5 | 10.37 |
| 380765 | 04/22/2002 | 5 | 7.5 | 10.32 |
| 380765 | 04/22/2002 | 6 | 7.2 | 10.25 |
| 380765 | 04/22/2002 | 7 | 7.4 | 10.13 |
| | | | | |
| 380765 | 07/24/2002 | 0.5 | 24.8 | 10.8 |
| 380765 | 07/24/2002 | 1 | 23.3 | 9.84 |
| 380765 | 07/24/2002 | 2 | 23.0 | 6.63 |
| 380765 | 07/24/2002 | 3 | 22.9 | 5.87 |
| 380765 | 07/24/2002 | 4 | 22.7 | 5.06 |
| 380765 | 07/24/2002 | 5 | 22.6 | 4.19 |
| | | | | |
| 380765 | 09/04/2002 | 0.5 | 20.4 | 7.42 |
| 380765 | 09/04/2002 | 1 | 20.2 | 7.92 |
| 380765 | 09/04/2002 | 2 | 20.1 | 7.77 |

| | | | | |
|---|---|---|---|---|
| 380765 | 09/04/2002 | 3 | 20.1 | 7.69 |
| 380765 | 09/04/2002 | 4 | 19.9 | 7.13 |
| 380765 | 09/04/2002 | 5 | 19.8 | 6.91 |
| 380765 | 09/04/2002 | 6 | 15.7 | 6.67 |
| | | | | |
| 380765 | 02/27/2003 | 0.5 | 2.7 | 13.97 |
| 380765 | 02/27/2003 | 1 | 3.3 | 13.55 |
| 380765 | 02/27/2003 | 2 | 3.2 | 13.20 |
| 380765 | 02/27/2003 | 3 | 3.2 | 12.95 |
| 380765 | 02/27/2003 | 4 | 3.2 | 12.75 |
| 380765 | 02/27/2003 | 5 | 3.2 | 11.95 |
| 380765 | 02/27/2003 | 6 | 3.2 | 7.78 |
| | | | | |
| 380765 | 05/27/2003 | 0.5 | 16.9 | 9.28 |
| 380765 | 05/27/2003 | 1 | 16.9 | 9.24 |
| 380765 | 05/27/2003 | 2 | 16.9 | 9.08 |
| 380765 | 05/27/2003 | 3 | 16.6 | 8.82 |
| 380765 | 05/27/2003 | 4 | 16.5 | 8.62 |
| 380765 | 05/27/2003 | 5 | 16.5 | 8.42 |
| 380765 | 05/27/2003 | 6 | 16.5 | 8.28 |
| 380765 | 05/27/2003 | 7 | 16.4 | 8.15 |
| 380765 | 05/27/2003 | 7.5 | 16.4 | 8.11 |
| | | | | |
| 380765 | 06/07/2003 | 0.5 | 20.9 | 10.10 |
| 380765 | 06/07/2003 | 1 | 20.8 | 10.06 |
| 380765 | 06/07/2003 | 2 | 20.5 | 9.47 |
| 380765 | 06/07/2003 | 3 | 19.8 | 8.91 |
| 380765 | 06/07/2003 | 4 | 18.3 | 8.00 |
| 380765 | 06/07/2003 | 5 | 17.1 | 7.12 |
| 380765 | 06/07/2003 | 6 | 16.4 | 6.66 |
| 380765 | 06/07/2003 | 7 | 16.0 | 5.18 |
| | | | | |
| 380765 | 07/22/2003 | 0.5 | 23.1 | 8.65 |
| 380765 | 07/22/2003 | 1 | 23.0 | 8.52 |
| 380765 | 07/22/2003 | 2 | 22.9 | 8.22 |
| 380765 | 07/22/2003 | 3 | 22.9 | 8.09 |
| 380765 | 07/22/2003 | 4 | 22.8 | 7.91 |
| 380765 | 07/22/2003 | 5 | 22.6 | 6.72 |
| 380765 | 07/22/2003 | 6 | 22.0 | 1.66 |
| 380765 | 07/22/2003 | 7 | 21.5 | 0.71 |
| | | | | |
| 380765 | 10/07/2003 | 0.5 | 13.1 | 13.4 |
| 380765 | 10/07/2003 | 1 | 13.0 | 13.52 |
| 380765 | 10/07/2003 | 2 | 12.6 | 11.11 |
| 380765 | 10/07/2003 | 3 | 11.2 | 9.45 |
| 380765 | 10/07/2003 | 4 | 10.9 | 8.64 |
| 380765 | 10/07/2003 | 5 | 10.8 | 5.71 |
| 380765 | 10/07/2003 | 6 | 10.8 | 5.74 |
| 380765 | 10/07/2003 | 6.5 | 10.8 | 5.69 |
| | | | | |
| 380765 | 05/04/2004 | 0.5 | 12.3 | 9.97 |
| 380765 | 05/04/2004 | 1 | 11.8 | 9.86 |
| 380765 | 05/04/2004 | 2 | 11.6 | 9.39 |
| 380765 | 05/04/2004 | 3 | 11.5 | 9.04 |

| | | | | |
|---|---|---|---|---|
| 380765 | 05/04/2004 | 4 | 11.5 | 8.76 |
| 380765 | 05/04/2004 | 5 | 11.5 | 8.47 |
| 380765 | 05/04/2004 | 6 | 11.4 | 8.37 |
| 380765 | 05/04/2004 | 7 | 11.4 | 7.91 |
| | | | | |
| 380765 | 05/18/2004 | 0.5 | 13.1 | 11.24 |
| 380765 | 05/18/2004 | 1 | 13.1 | 11.02 |
| 380765 | 05/18/2004 | 2 | 13.1 | 11.06 |
| 380765 | 05/18/2004 | 3 | 13.2 | 11.06 |
| 380765 | 05/18/2004 | 4 | 13.2 | 10.99 |
| 380765 | 05/18/2004 | 5 | 11.0 | 10.15 |
| 380765 | 05/18/2004 | 6 | 10.7 | 9.25 |
| 380765 | 05/18/2004 | 7 | 10.6 | 9.34 |
| | | | | |
| 380765 | 06/08/2004 | 0.5 | 17.4 | 8.73 |
| 380765 | 06/08/2004 | 1 | 17.4 | 8.69 |
| 380765 | 06/08/2004 | 2 | 17.4 | 8.65 |
| 380765 | 06/08/2004 | 3 | 17.4 | 8.62 |
| 380765 | 06/08/2004 | 4 | 17.3 | 8.58 |
| 380765 | 06/08/2004 | 5 | 17.3 | 8.57 |
| 380765 | 06/08/2004 | 6 | 17.3 | 8.55 |
| 380765 | 06/08/2004 | 7 | 17.3 | 8.37 |
| | | | | |
| 380765 | 06/23/2004 | 0.5 | 16.6 | 9.46 |
| 380765 | 06/23/2004 | 1 | 16.6 | 9.34 |
| 380765 | 06/23/2004 | 2 | 16.6 | 9.20 |
| 380765 | 06/23/2004 | 3 | 16.6 | 9.09 |
| 380765 | 06/23/2004 | 4 | 16.6 | 8.99 |
| 380765 | 06/23/2004 | 5 | 16.6 | 8.91 |
| 380765 | 06/23/2004 | 6 | 16.6 | 8.86 |
| | | | | |
| 380765 | 07/20/2004 | 0.5 | 24.1 | 9.28 |
| 380765 | 07/20/2004 | 1 | 24.1 | 8.97 |
| 380765 | 07/20/2004 | 2 | 24.1 | 8.70 |
| 380765 | 07/20/2004 | 3 | 24.0 | 8.45 |
| 380765 | 07/20/2004 | 4 | 20.6 | 2.79 |
| 380765 | 07/20/2004 | 5 | 18.1 | 1.42 |
| 380765 | 07/20/2004 | 6 | 17.8 | 0.25 |
| 380765 | 07/20/2004 | 7 | 17.4 | 0.21 |
| 380765 | 07/20/2004 | 8 | 17.4 | 0.20 |
| | | | | |
| 380765 | 08/09/2004 | 0.5 | 19.0 | 6.10 |
| 380765 | 08/09/2004 | 1 | 19.1 | 6.03 |
| 380765 | 08/09/2004 | 2 | 19.1 | 5.97 |
| 380765 | 08/09/2004 | 3 | 19.1 | 5.88 |
| 380765 | 08/09/2004 | 4 | 19.1 | 5.80 |
| 380765 | 08/09/2004 | 5 | 19.1 | 5.65 |
| 380765 | 08/09/2004 | 6 | 19.1 | 5.62 |
| 380765 | 08/09/2004 | 7 | 19.1 | 5.20 |
| | | | | |
| 380765 | 09/22/2004 | 0.5 | 15.7 | 5.31 |
| 380765 | 09/22/2004 | 1 | 15.7 | 5.20 |
| 380765 | 09/22/2004 | 2 | 15.7 | 5.09 |
| 380765 | 09/22/2004 | 3 | 15.7 | 5.00 |

| | | | | |
|---|---|---|---|---|
| 380765 | 09/22/2004 | 4 | 15.7 | 4.96 |
| 380765 | 09/22/2004 | 5 | 15.7 | 4.94 |
| 380765 | 09/22/2004 | 6 | 15.6 | 4.09 |
| | | | | |
| 380765 | 11/15/2004 | 0.5 | 3.6 | 11.67 |
| 380765 | 11/15/2004 | 1 | 3.5 | 11.66 |
| 380765 | 11/15/2004 | 2 | 3.5 | 11.56 |
| 380765 | 11/15/2004 | 3 | 3.4 | 11.56 |
| 380765 | 11/15/2004 | 4 | 3.4 | 11.48 |
| 380765 | 11/15/2004 | 5 | 3.4 | 11.40 |
| 380765 | 11/15/2004 | 6 | 3.4 | 11.30 |
| | | | | |
| 380765 | 01/24/2005 | 0.5 | 1.0 | 10.41 |
| 380765 | 01/24/2005 | 1 | 1.6 | 10.30 |
| 380765 | 01/24/2005 | 2 | 1.7 | 10.28 |
| 380765 | 01/24/2005 | 3 | 1.6 | 10.94 |
| 380765 | 01/24/2005 | 4 | 1.5 | 10.41 |
| 380765 | 01/24/2005 | 5 | 2.0 | 9.36 |
| 380765 | 01/24/2005 | 6 | 1.8 | 9.55 |
| 380765 | 01/24/2005 | 7 | 1.7 | 9.45 |
| | | | | |
| 380765 | 02/16/2005 | 0.5 | 1.3 | 13.20 |
| 380765 | 02/16/2005 | 1 | 4.0 | 12.82 |
| 380765 | 02/16/2005 | 2 | 4.1 | 13.38 |
| 380765 | 02/16/2005 | 3 | 3.4 | 12.25 |
| 380765 | 02/16/2005 | 4 | 3.3 | 11.88 |
| 380765 | 02/16/2005 | 5 | 3.0 | 10.28 |
| 380765 | 02/16/2005 | 6 | 2.5 | 9.14 |